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Salib

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(54) **SYSTEMS, METHODS AND APPARATUS FOR MONITORING CONDITIONS OF PHYSICAL OR VIRTUAL OBJECTS**

(71) Applicant: **James Madison Innovations, Inc.**, Harrisonburg, VA (US)

(72) Inventor: **Emil Habib Salib**, Harrisonburg, VA (US)

(73) Assignee: **James Madison Innovations, Inc.**, Harrisonburg, VA (US)

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Related U.S. Application Data

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(51) **Int. Cl.**

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G01F 23/22	(2006.01)
G01F 15/06	(2022.01)
G01F 15/063	(2022.01)

(52) **U.S. Cl.**

CPC ***G01F 23/68*** (2013.01); ***G01F 15/063*** (2013.01); ***G01F 23/22*** (2013.01)

(58) **Field of Classification Search**

CPC G01F 23/68; G01F 15/063; G01F 23/22

See application file for complete search history.

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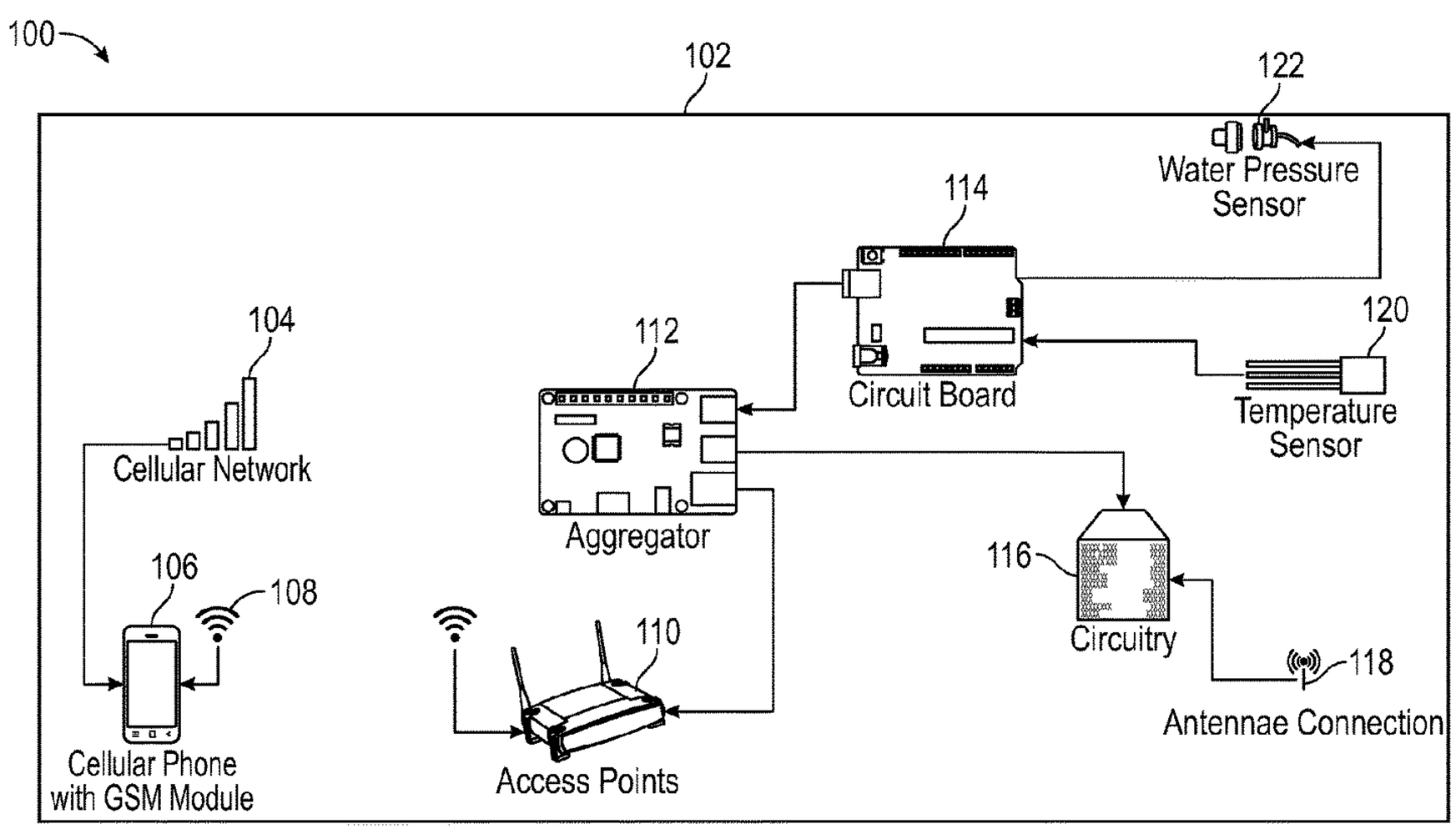
Primary Examiner — Sisay Yacob

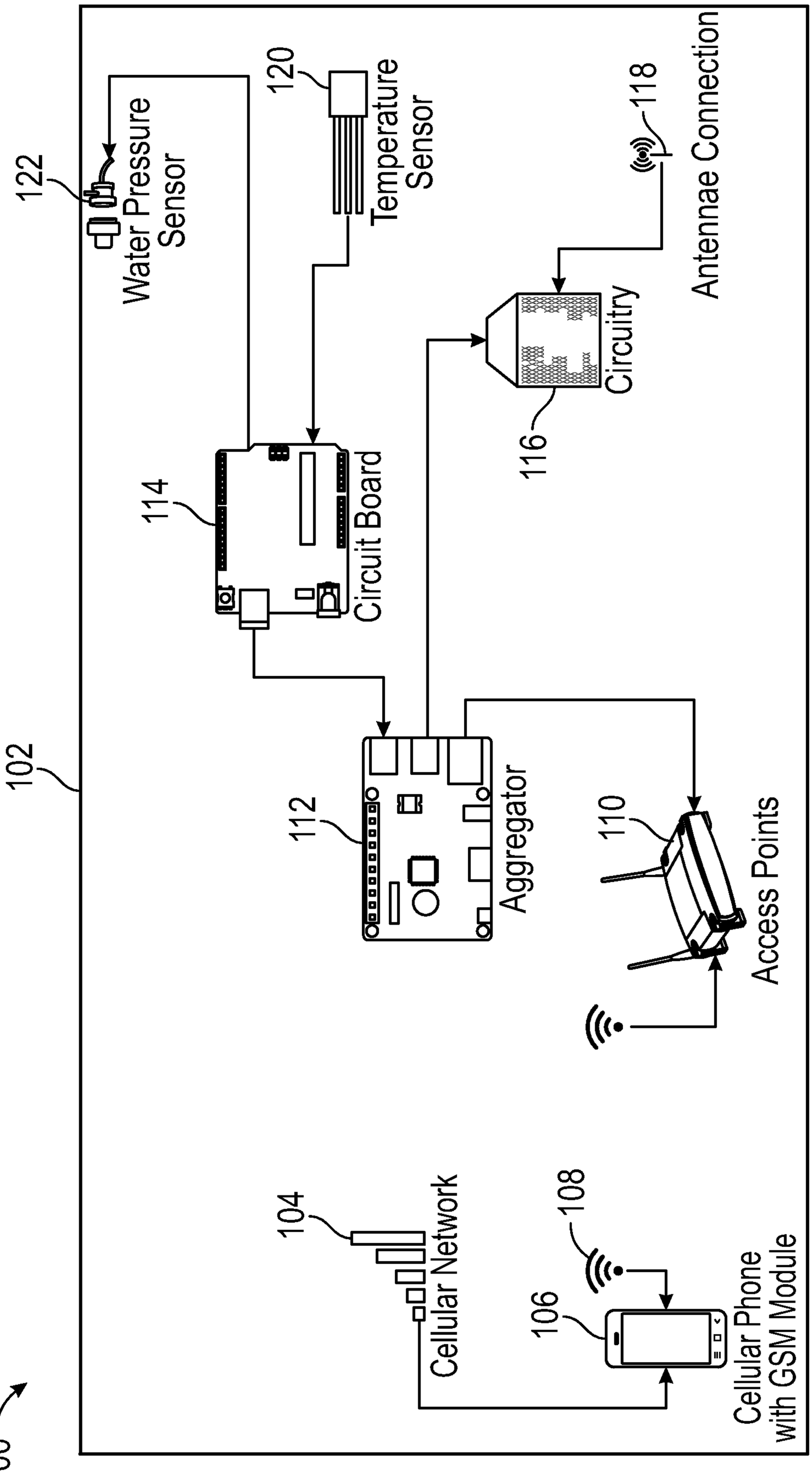
(74) *Attorney, Agent, or Firm* — Leveque IP Law, P.C.

(57) **ABSTRACT**

A system, method and apparatus for providing real-time alerts regarding the status of agricultural infrastructure resources, which may be stationary and/or mobile, such as water level, water temperature, trough, water pump, drone, and livestock that are equipped with sensors. The system adaptively aggregates and processes the sensed data from multiple resources and animals using low cost readily available wireless local network and sends an alert cost effectively using various messaging methods, such as SMS, MMS, PSTN, VoIP, HTTP, and HTTPS, over various wireless communications networks, such as cellular, satellite, or UHF, depending on availability, cost and quality of service.

13 Claims, 14 Drawing Sheets

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102
104
Cellular Network
106
108
Cellular Phone
with GSM Module
110
Access Points
112
Aggregator
114
Circuit Board
116
Circuitry
118
Antennae Connection
120
Temperature
Sensor
122
Water Pressure
Sensor
Pump House

FIG. 1

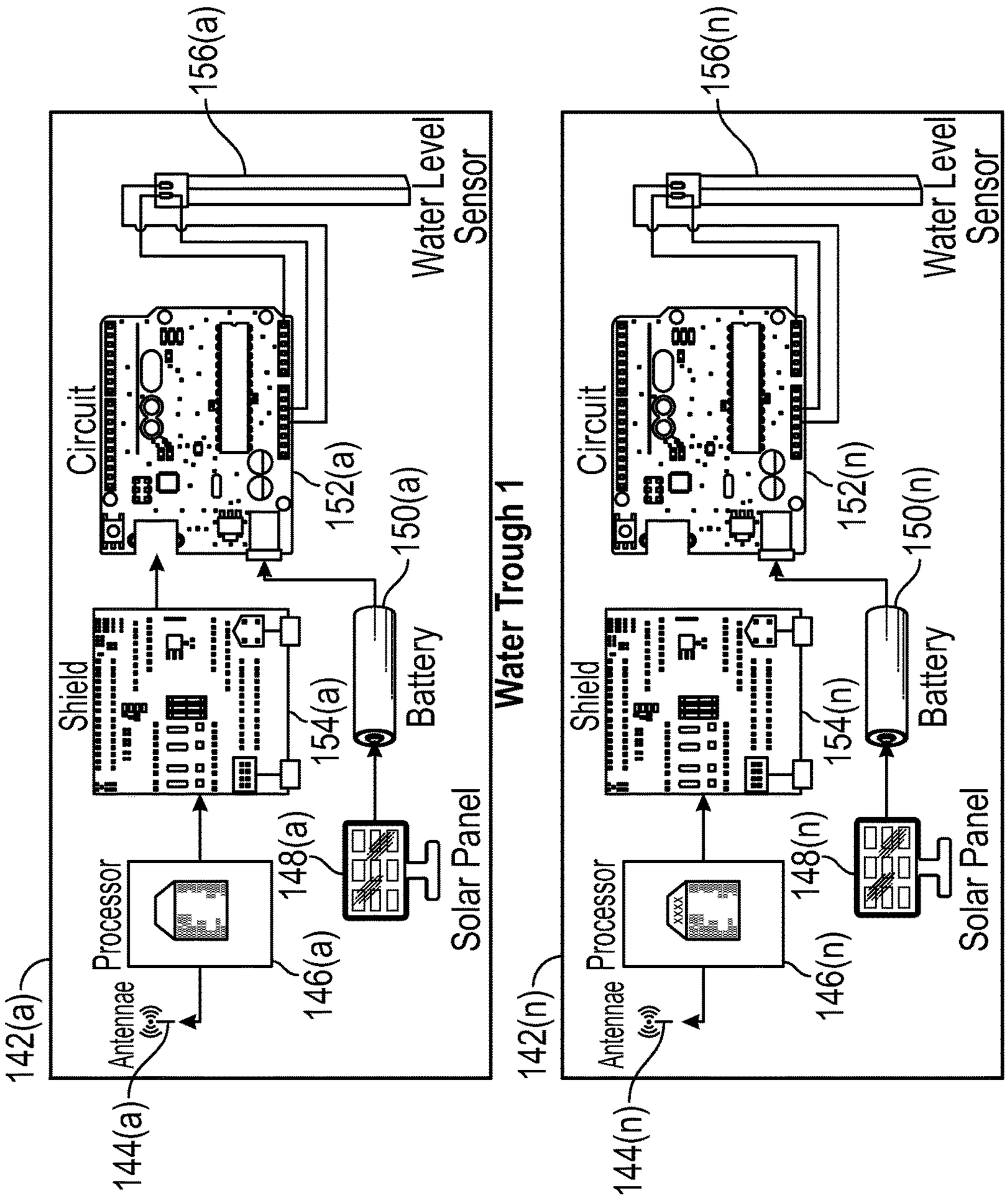
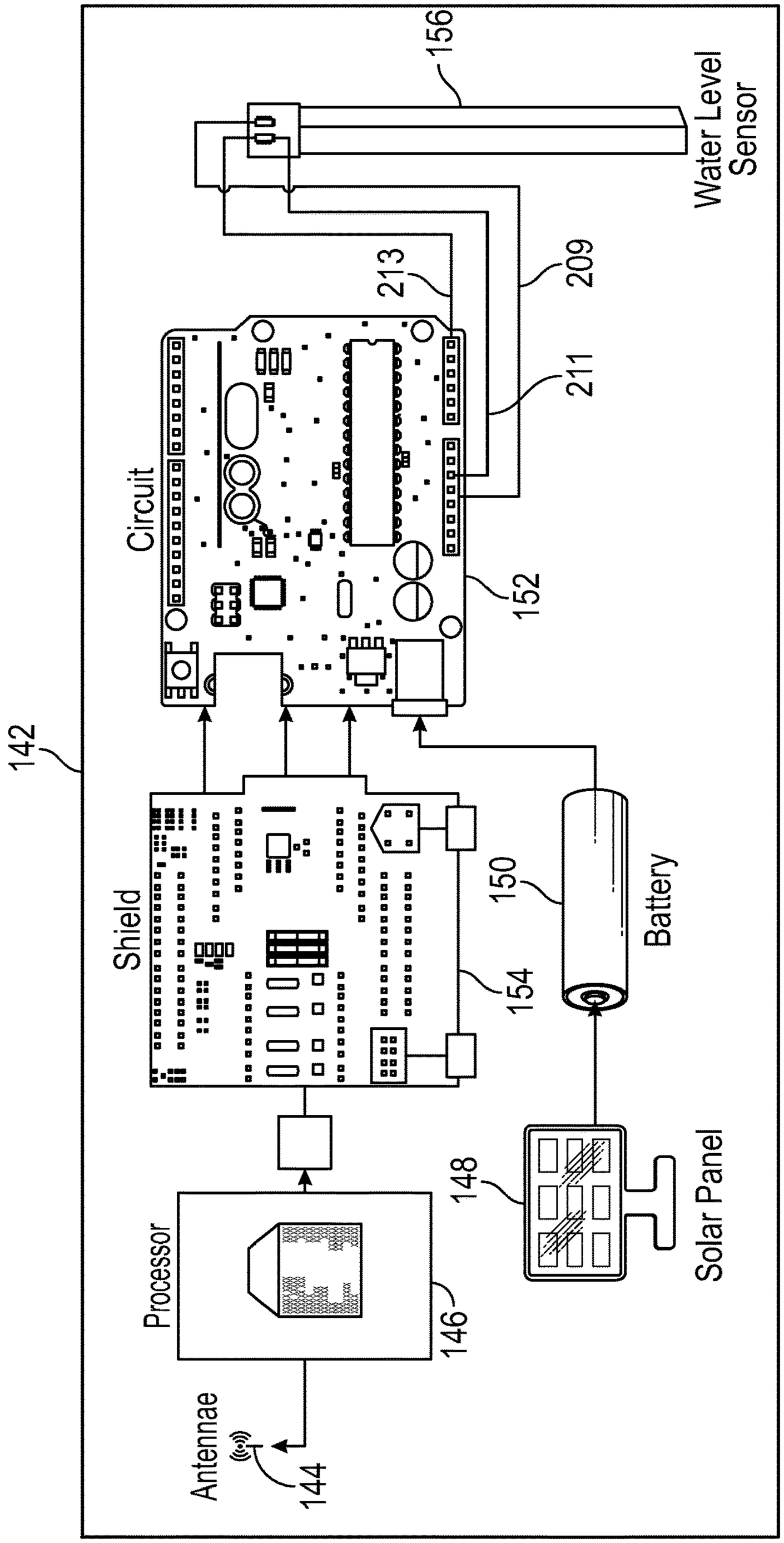


FIG. 1 (Continued)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Water Level Sensor
213
209
211
Circuit
152
142
Shield
150
Battery
154
148
Solar Panel
Processor
146
Antennae
144

FIG. 2

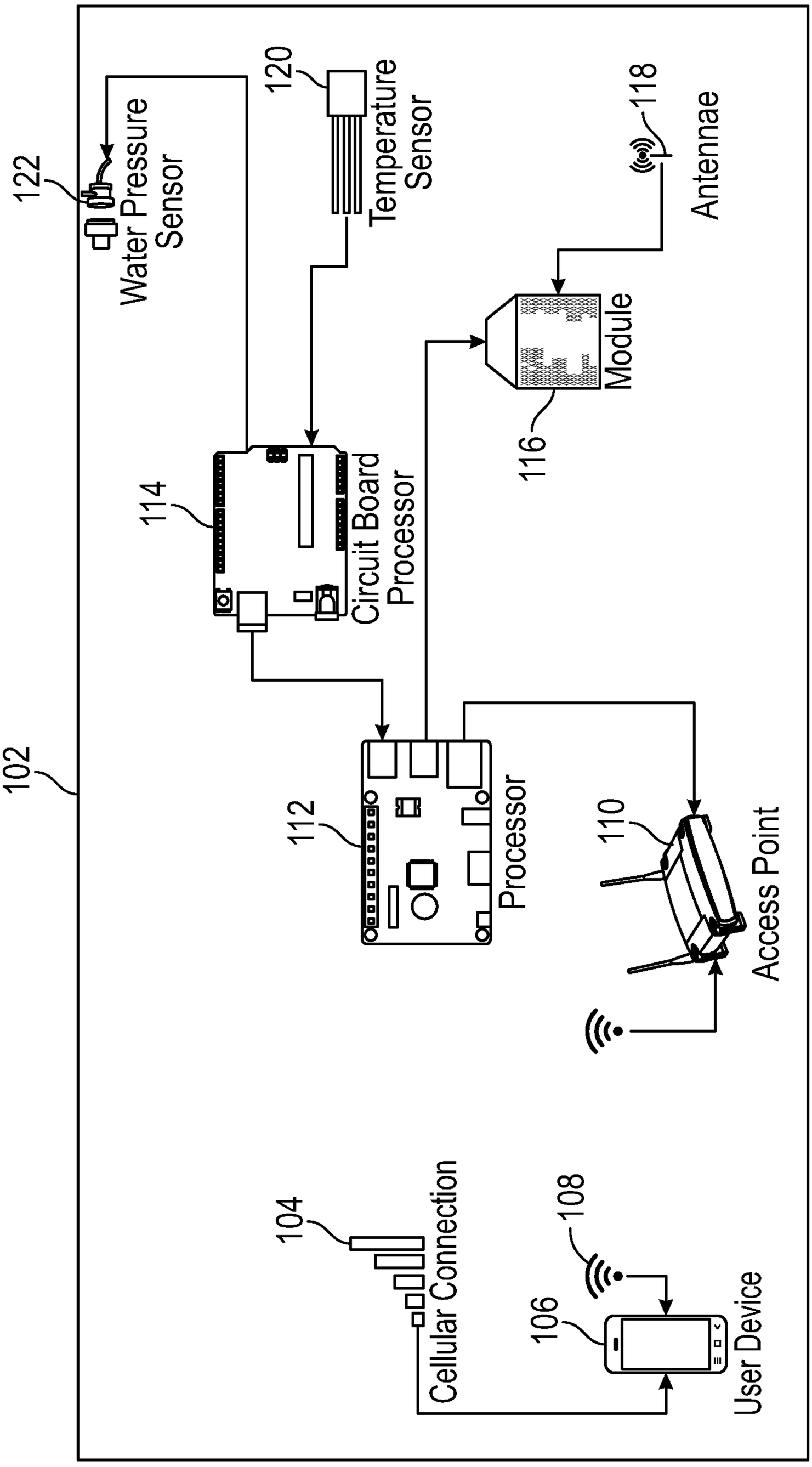
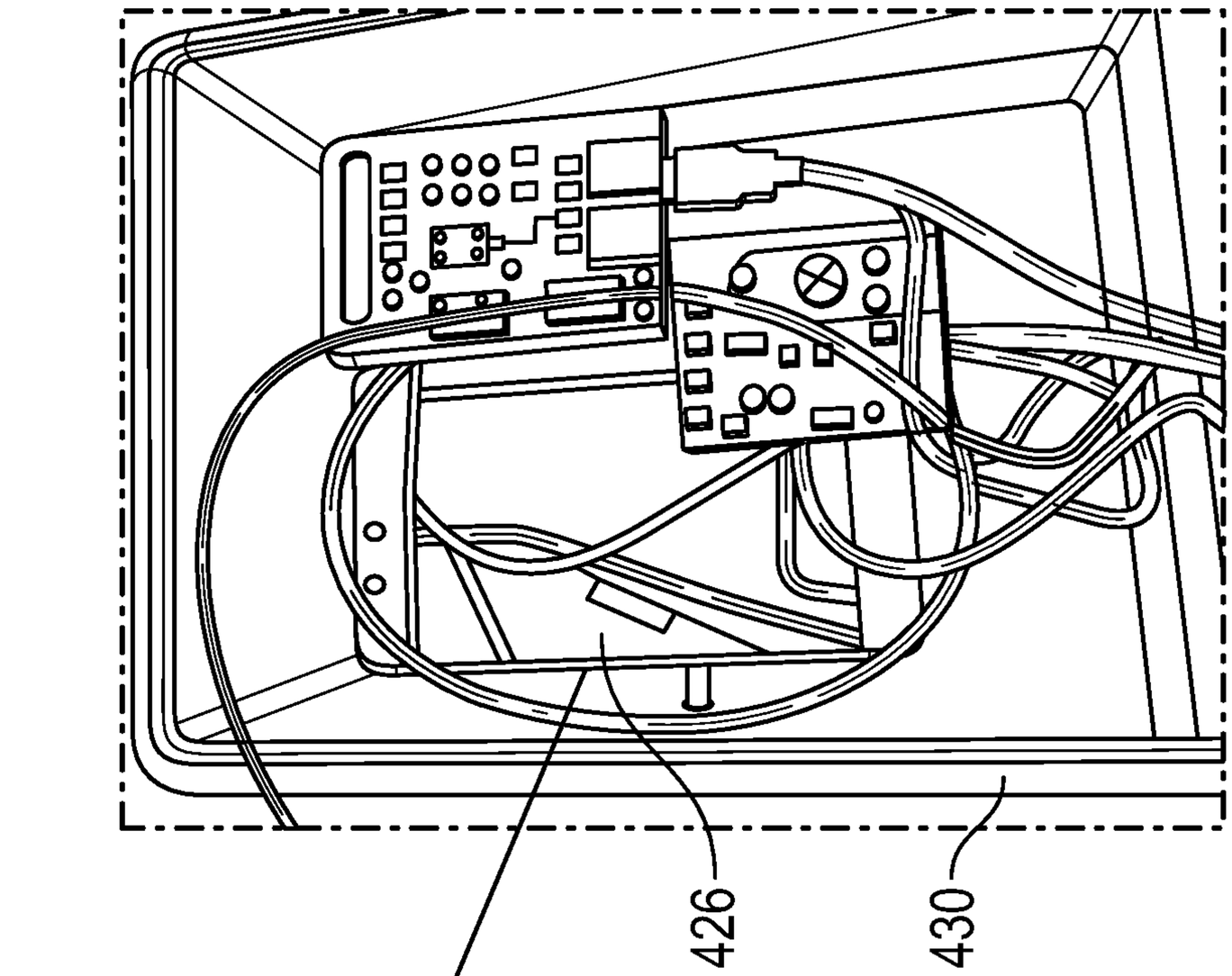
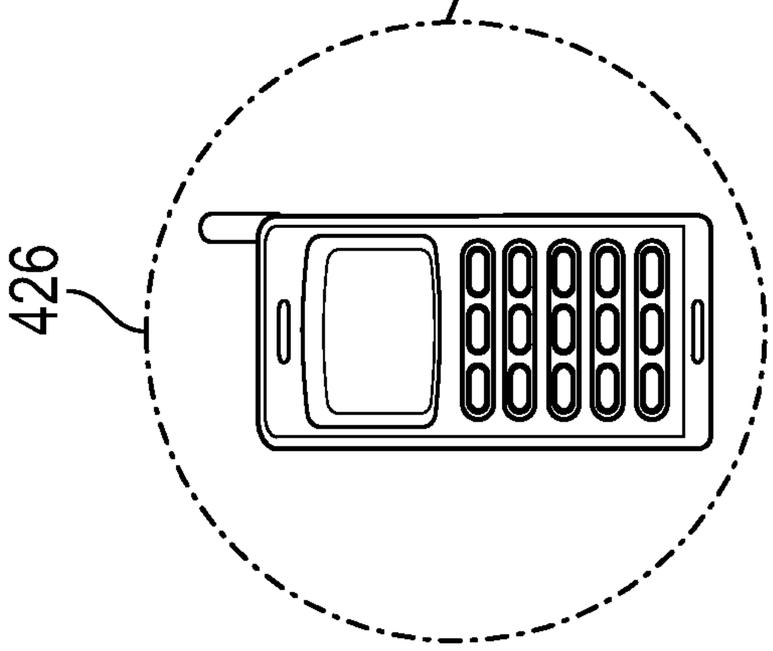

102
104
Cellular Connection
106
108
User Device
110
Access Point
112
Processor
114
Circuit Board Processor
116
118
Antennae
120
Temperature Sensor
122
Water Pressure Sensor
Module

FIG. 3


426
430


426
GSM Modem - An Android App Running on Our Android Phone

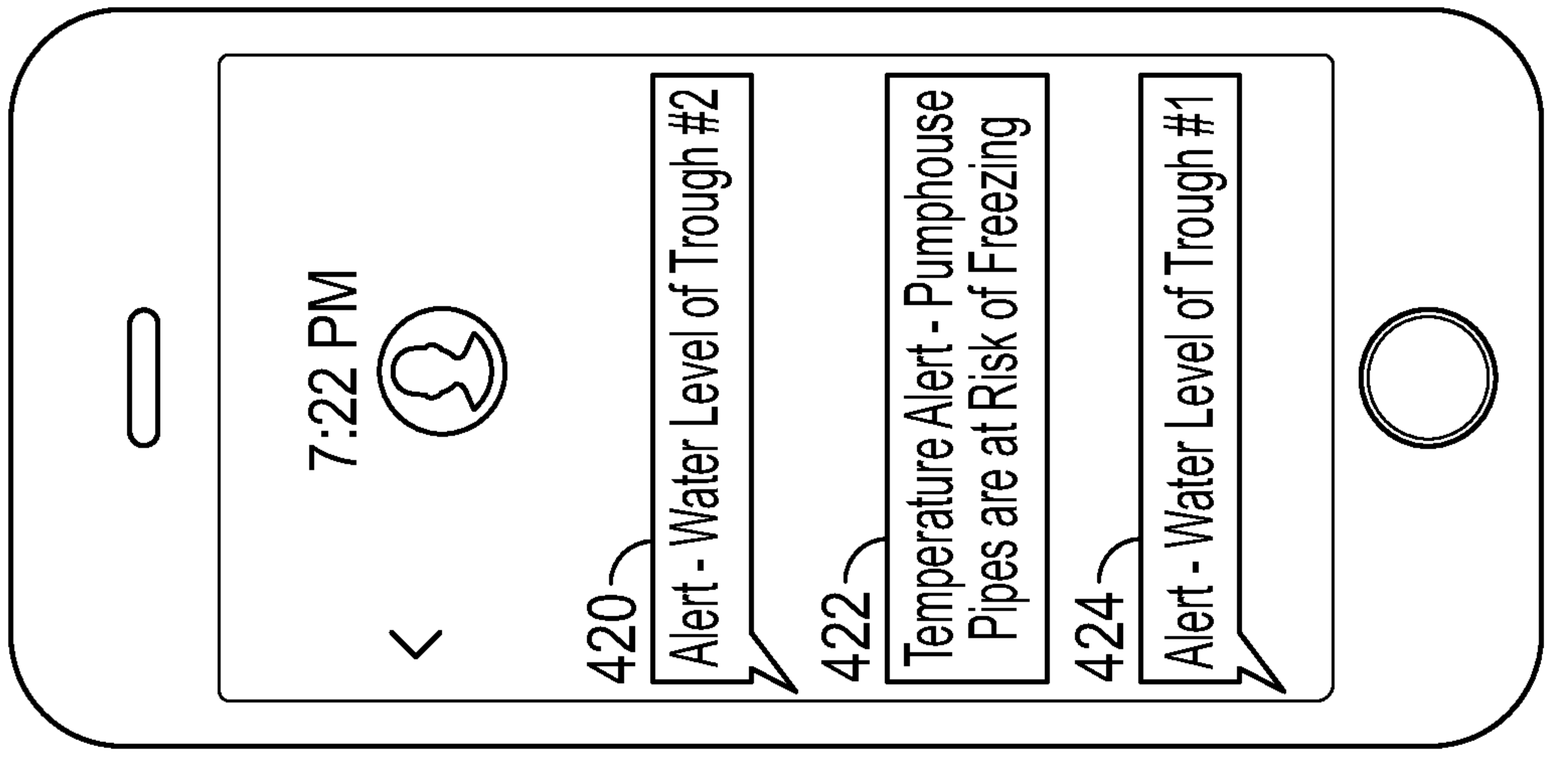

7:22 PM
420
Alert - Water Level of Trough #2
422
Temperature Alert - Pumphouse Pipes are at Risk of Freezing
424
Alert - Water Level of Trough #1

FIG. 4

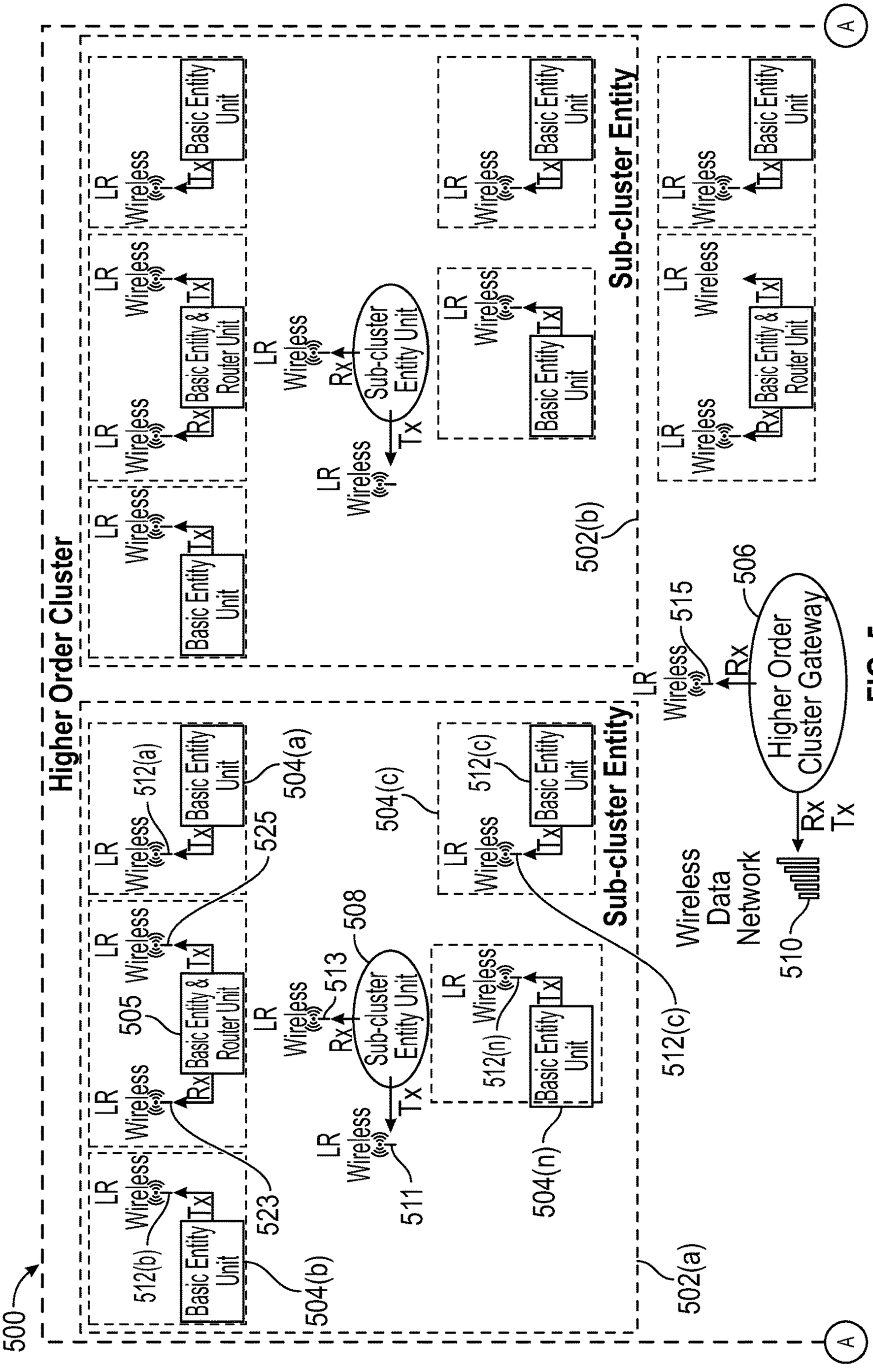

500
Higher Order Cluster
Sub-cluster Entity
502(a)
502(b)
LR Wireless
Basic Entity Unit
Basic Entity & Router Unit
Sub-cluster Entity Unit
Higher Order Cluster Gateway
Wireless Data Network
504(a)
504(b)
504(c)
504(n)
505
506
508
510
511
512(a)
512(b)
512(c)
512(n)
513
515
523
525
A

FIG. 5

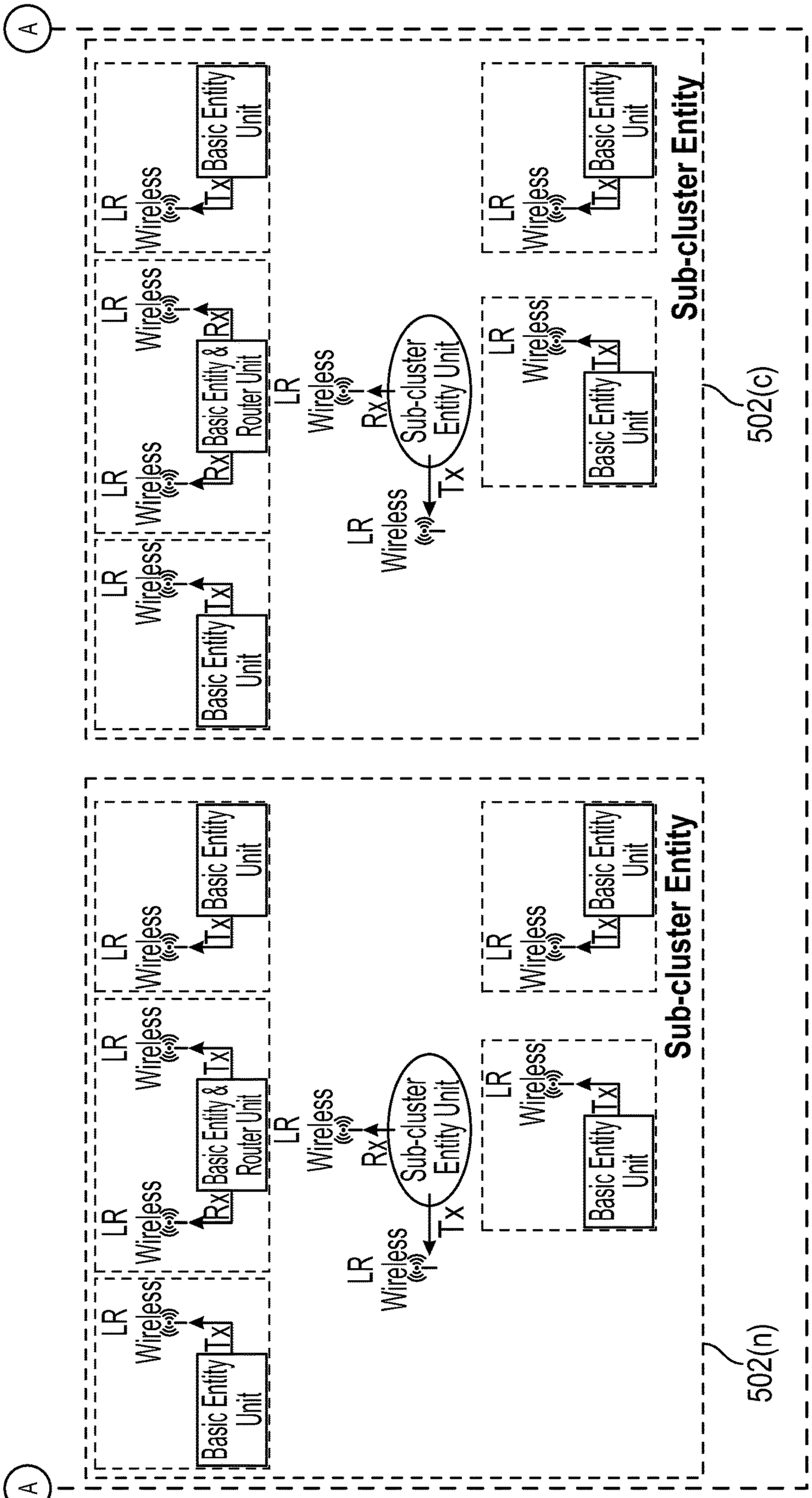


FIG. 5
(Continued)

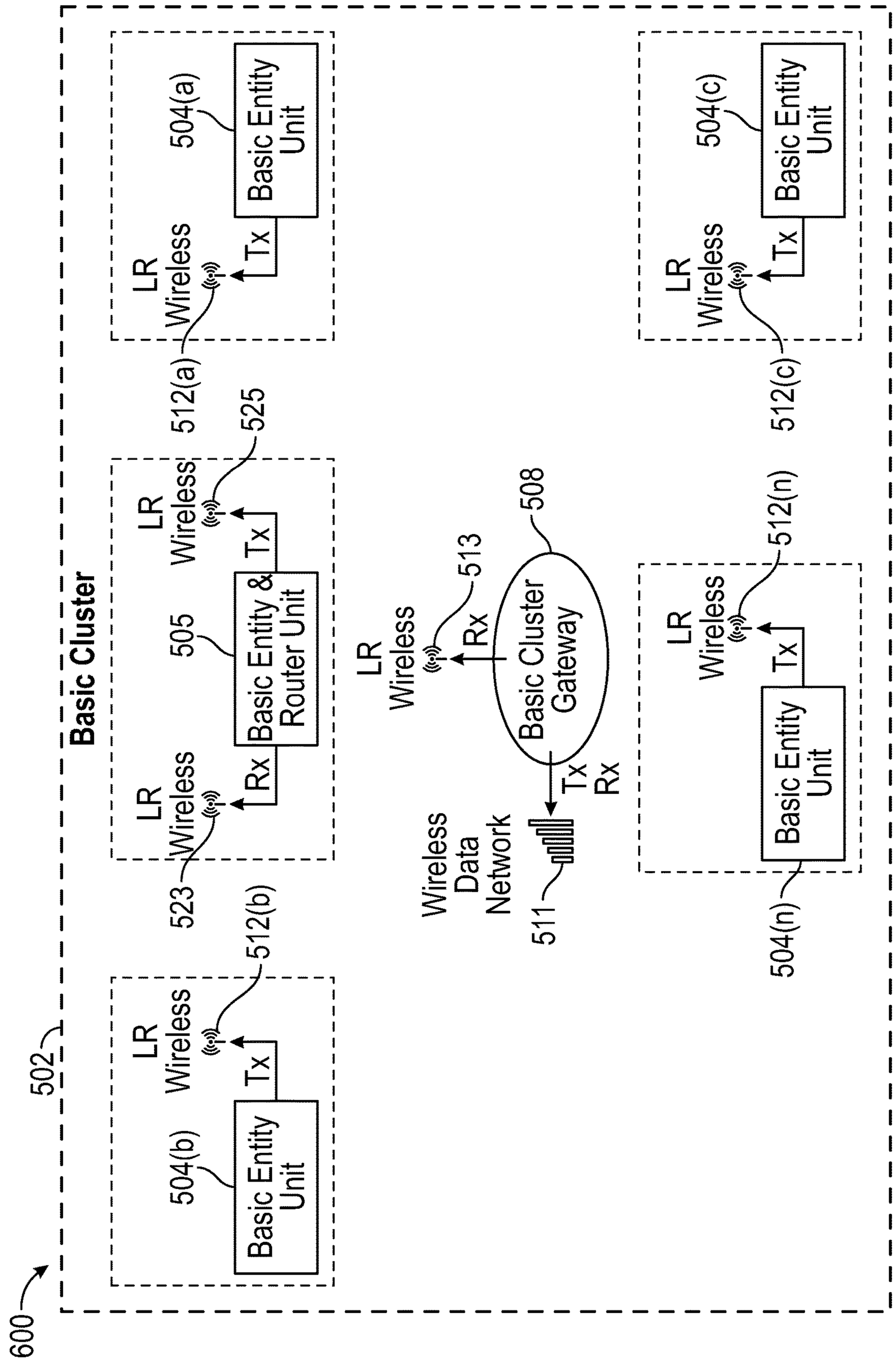

600
Basic Cluster
502
LR Wireless
504(a)
Basic Entity Unit
Tx
512(a)
LR Wireless
504(c)
Basic Entity Unit
Tx
512(c)
LR Wireless
525
Basic Entity & Router Unit
505
Rx
523
512(b)
LR Wireless
513
Rx
Basic Cluster Gateway
508
Tx
Rx
Wireless Data Network
511
LR Wireless
512(n)
Tx
Basic Entity Unit
504(n)
LR Wireless
504(b)
Basic Entity Unit
Tx

FIG. 6

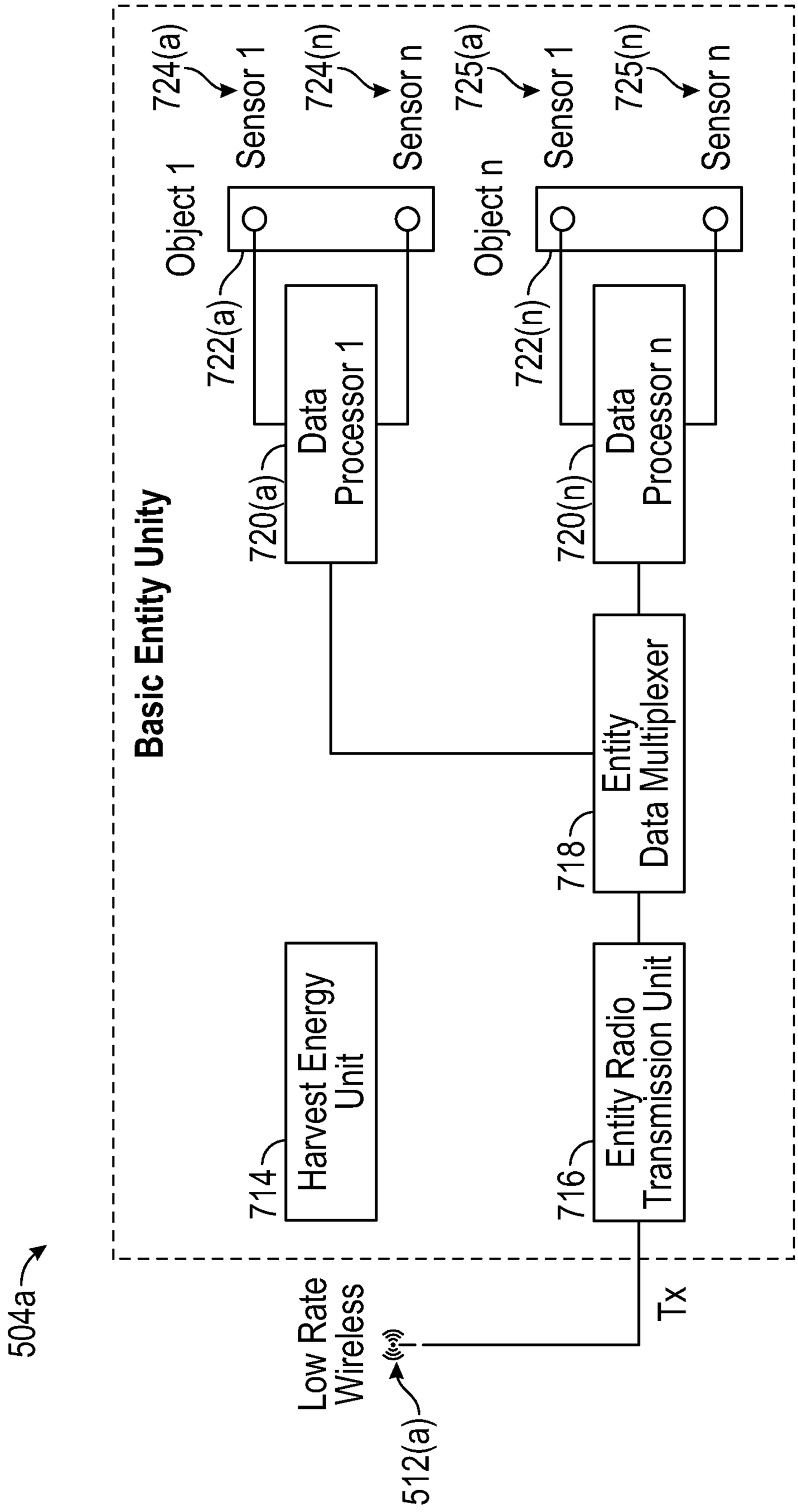

Basic Entity Unity
504a
Object 1
Object n
724(a)
Sensor 1
724(n)
Sensor n
725(a)
Sensor 1
725(n)
Sensor n
722(a)
722(n)
720(a)
720(n)
Data Processor 1
Data Processor n
718
Entity Data Multiplexer
714
Harvest Energy Unit
716
Entity Radio Transmission Unit
Low Rate Wireless
512(a)
Tx

FIG. 7

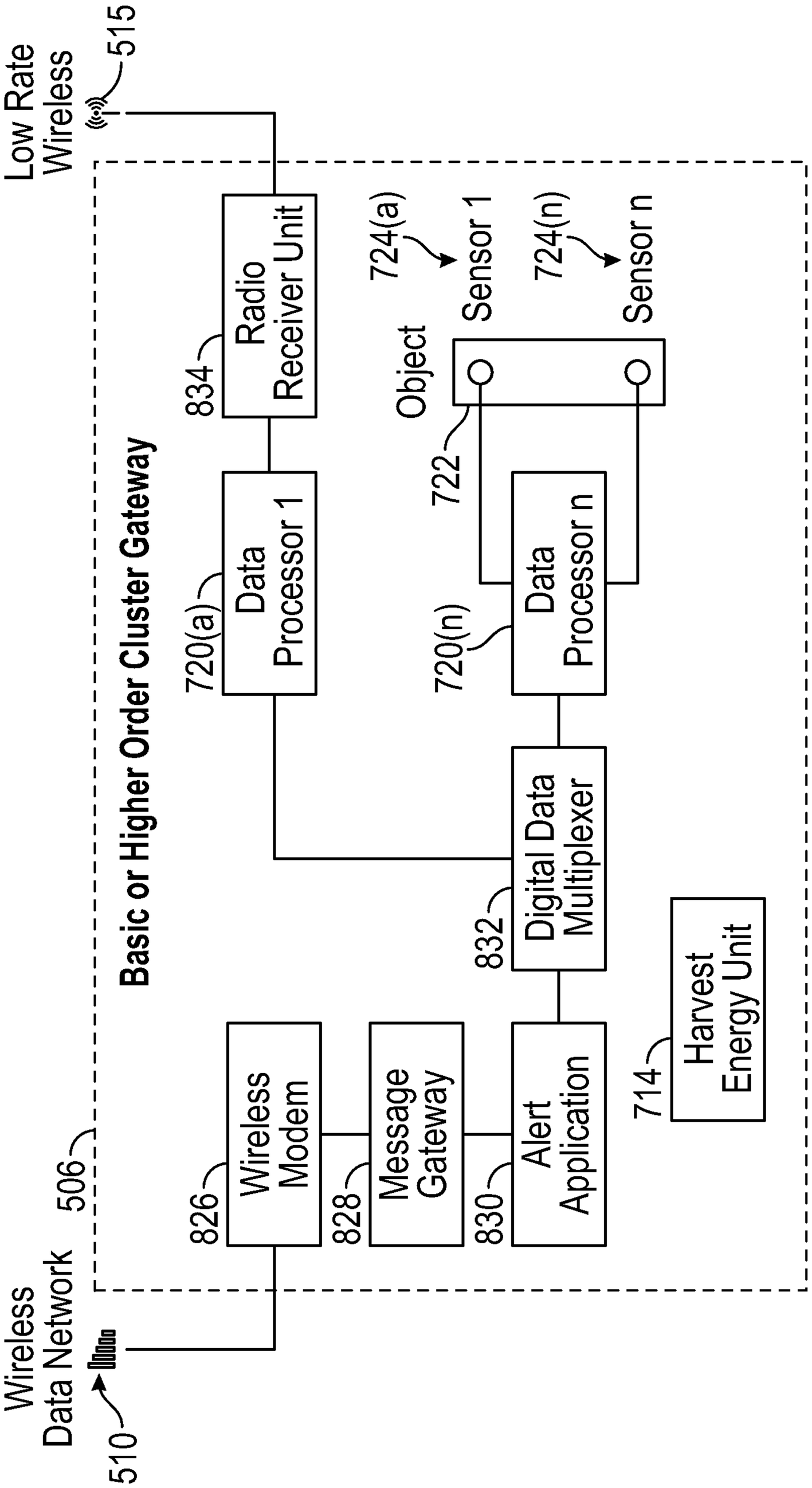

Low Rate Wireless
515
Basic or Higher Order Cluster Gateway
834
Radio Receiver Unit
720(a)
Data Processor 1
724(a)
Sensor 1
724(n)
Sensor n
Object
722
720(n)
Data Processor n
832
Digital Data Multiplexer
826
Wireless Modem
828
Message Gateway
830
Alert Application
714
Harvest Energy Unit
506
Wireless Data Network
510

FIG. 8

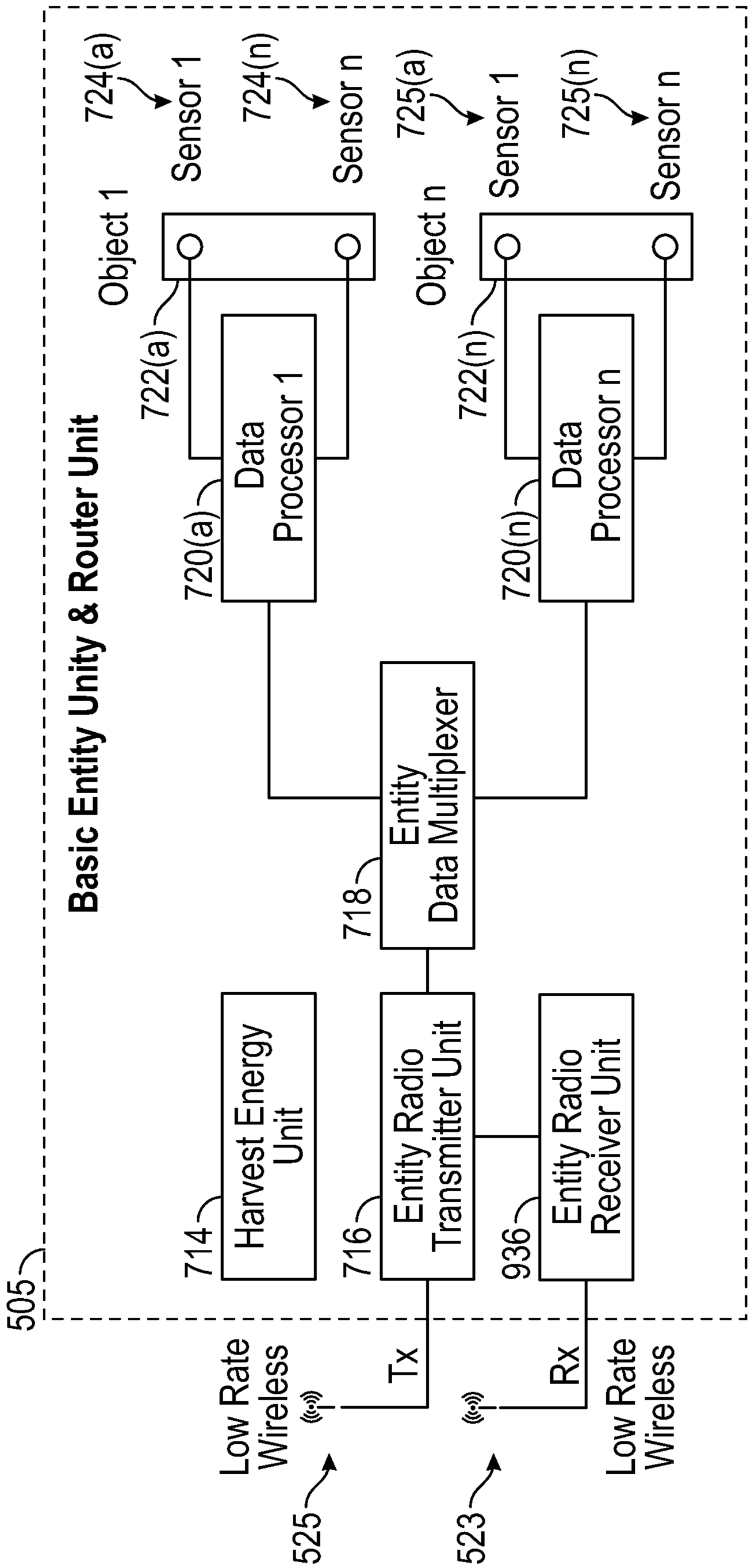

Basic Entity Unity & Router Unit
505
Object 1
724(a)
Sensor 1
724(n)
Sensor n
722(a)
720(a)
Data Processor 1
Object n
725(a)
Sensor 1
725(n)
Sensor n
722(n)
720(n)
Data Processor n
718
Entity Data Multiplexer
714
Harvest Energy Unit
716
Entity Radio Transmitter Unit
936
Entity Radio Receiver Unit
Low Rate Wireless
Tx
Rx
Low Rate Wireless
525
523

FIG. 9

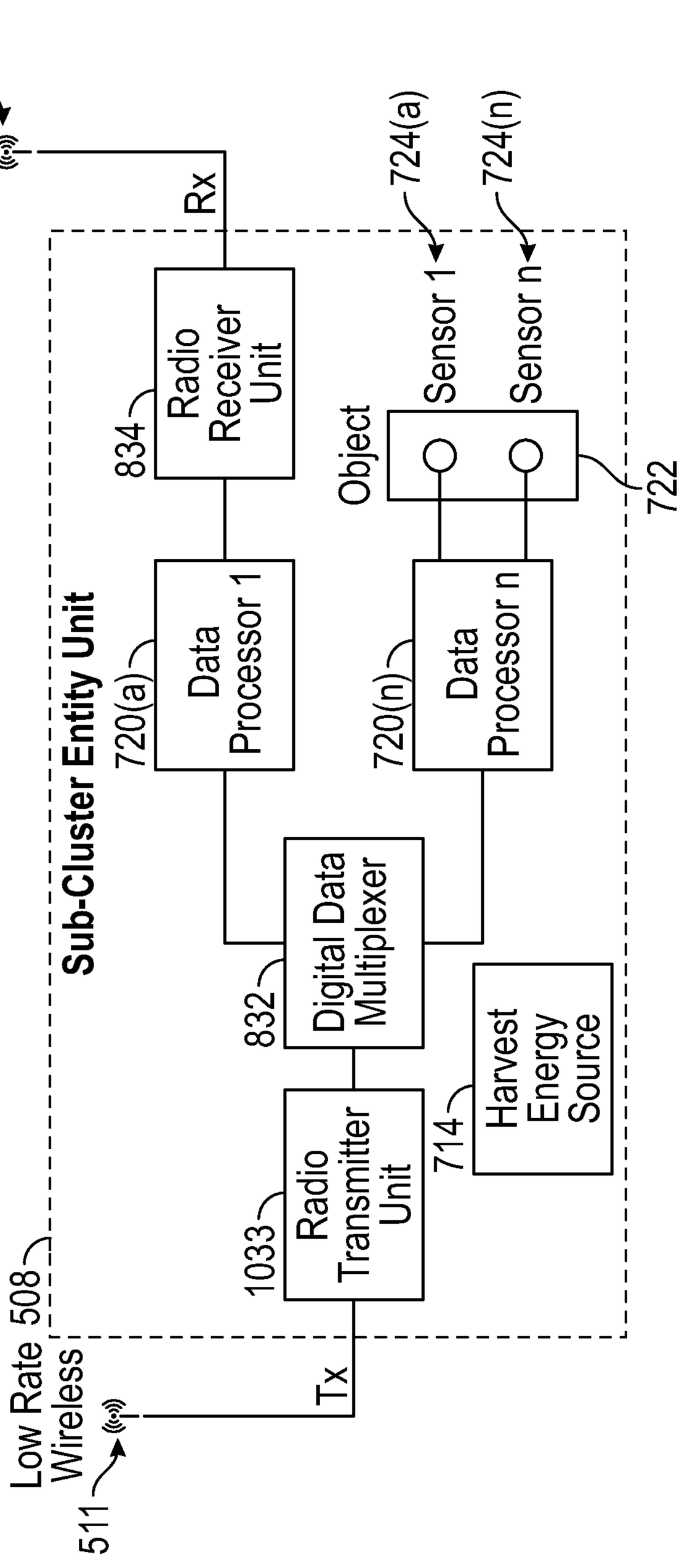

Low Rate Wireless
513
Rx
724(a)
724(n)
Sub-Cluster Entity Unit
834
Radio Receiver Unit
720(a)
Data Processor 1
Object
Sensor 1
Sensor n
722
720(n)
Data Processor n
832
Digital Data Multiplexer
1033
Radio Transmitter Unit
714
Harvest Energy Source
508
Low Rate Wireless
511
Tx

FIG. 10

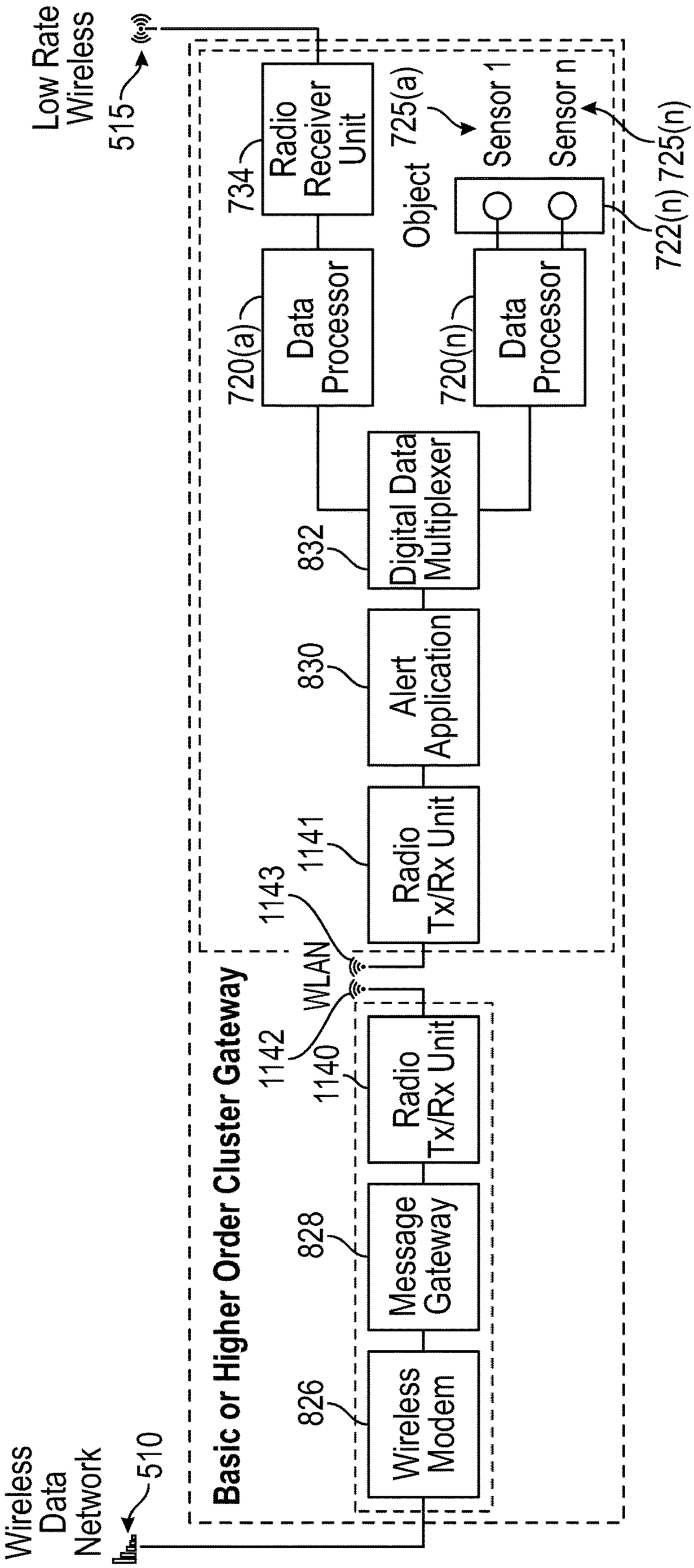

Wireless Data Network
510
Basic or Higher Order Cluster Gateway
826
Wireless Modem
828
Message Gateway
1140
Radio Tx/Rx Unit
1142
WLAN
1143
1141
Radio Tx/Rx Unit
830
Alert Application
832
Digital Data Multiplexer
734
Radio Receiver Unit
720(a)
Data Processor
720(n)
Data Processor
Object
725(a)
Sensor 1
Sensor n
722(n) 725(n)
Low Rate Wireless
515

FIG. 11

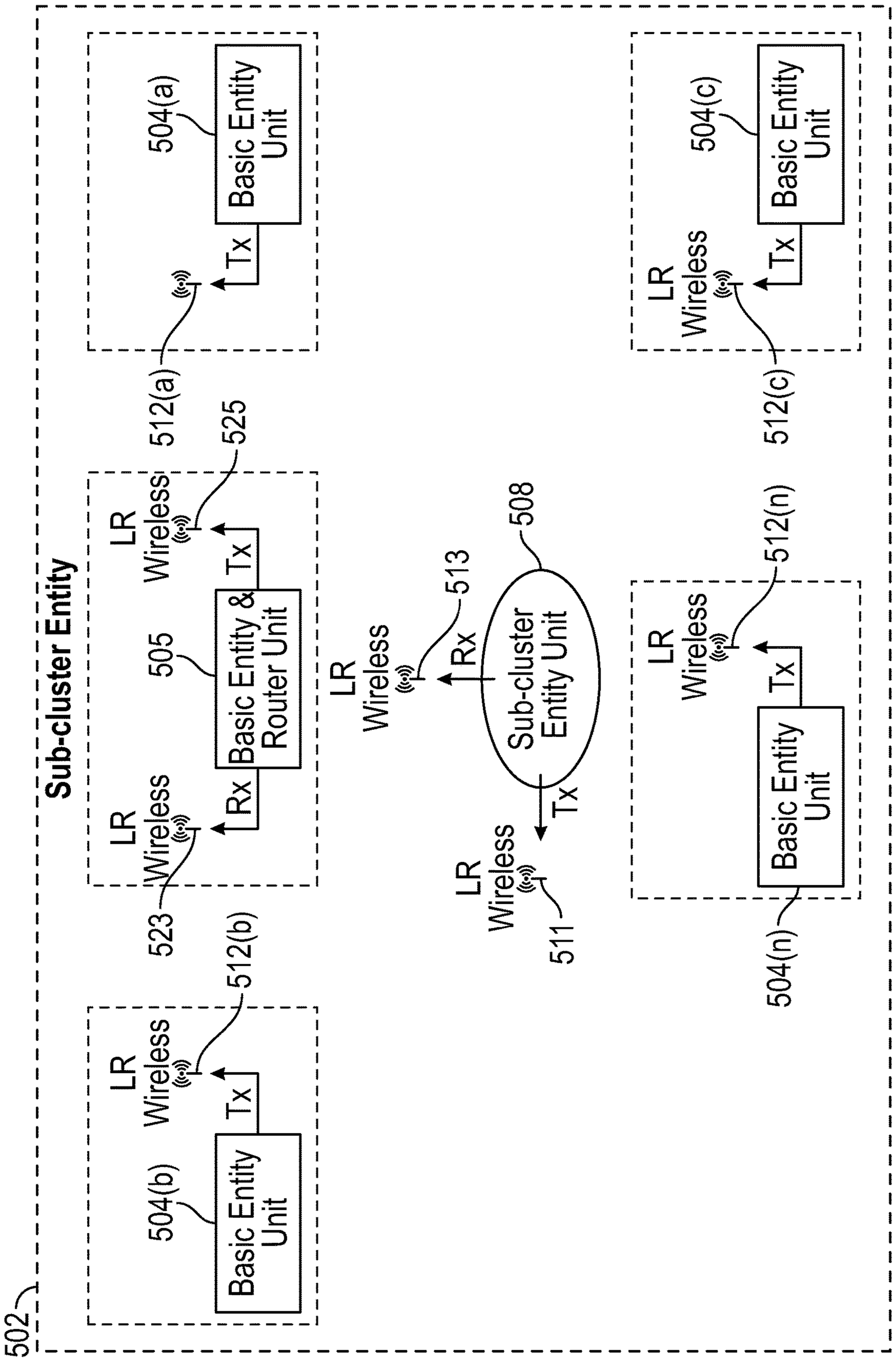

502
Sub-cluster Entity
504(a)
Basic Entity Unit
Tx
LR Wireless
512(a)
504(c)
Basic Entity Unit
Tx
LR Wireless
512(c)
523
LR Wireless
512(b)
505
Basic Entity & Router Unit
525
Rx
Tx
LR Wireless
513
Rx
508
Sub-cluster Entity Unit
Tx
LR Wireless
511
LR Wireless
512(n)
Basic Entity Unit
Tx
504(n)
504(b)
Basic Entity Unit
LR Wireless
512(b)
Tx

FIG. 12

SYSTEMS, METHODS AND APPARATUS FOR MONITORING CONDITIONS OF PHYSICAL OR VIRTUAL OBJECTS

FIELD OF THE DISCLOSURE

The present disclosure relates to adaptively monitoring, collecting and analyzing sensed data generated by sensors located on stationary and mobile physical and/or virtual objects over optimized and secure communications channels. Alerts and/or notifications based on the adaptive processing of sensor data and/or aggregated sensor data are generated and communicated securely and wirelessly. Actuators are used to control physical and/or virtual objects.

BACKGROUND

Today, society is faced with a wide range of environmental problems that are continuing to grow in severity. If left unchecked these problems can lead to long term damage to not only the environment but also to the living beings in the environment. To tackle these problems, it is the responsibility of humans to develop a plan to reduce the severity of environmental problems. One such plan includes an initiative the United States Department of Agriculture developed to encourage farmers to cutoff their lands from adjacent streams and waterways. By doing this, runoff from these farms does not flow into the waterway and contaminate watersheds. In return for fencing off their lands the Department of Agriculture provides, at least in the short term, financial assistance to these farmers in order to help the farmers return to normal operating functions of their farm.

BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings, which are incorporated in and constitute a part of this specification, illustrate embodiments of the present disclosure and, together with a general description given above, and the detailed description given below, serve to explain the principles of the present disclosure.

FIG. **1** shows an embodiment that includes a pump house and two water troughs.

FIG. **2** shows components of a trough according to an embodiment of the disclosure.

FIG. **3** shows components of a pump house according to an embodiment of the disclosure.

FIG. **4** shows an embodiment of an alert transmission according to an embodiment of the disclosure.

FIG. **5** shows a representation of a group of adaptive sub-cluster entity units forming an adaptive cluster or an adaptive higher order cluster.

FIG. **6** shows a composition of one adaptive basic cluster.

FIG. **7** shows an example of an adaptive basic entity unit.

FIG. **8** shows a gateway configured to serve an adaptive basic cluster or an adaptive cluster (also called adaptive higher order cluster).

FIG. **9** shows an adaptive basic entity unit configured to act as an adaptive entity unit as well as a router unit.

FIG. **10** shows a configuration of an adaptive basic gateway configured as adaptive sub-cluster entity unit.

FIG. **11** shows an adaptive gateway that is configured so that the alert and/or notification application component communicates to the message gateway via a WLAN.

FIG. **12** shows an adaptive sub-cluster entity where adaptive basic entity units are served by an adaptive sub-cluster entity unit.

It should be understood that the appended drawings are not necessarily to scale, presenting a somewhat simplified representation of various features illustrative of the basic principles of the disclosure. The specific design features of the sequence of operations as disclosed herein, including, for example, specific dimensions, orientations, locations, and shapes of various illustrated components, will be determined in part by the particular intended application and use environment. Certain features of the illustrated embodiments have been enlarged or distorted relative to others to facilitate visualization and clear understanding. In particular, thin features may be thickened, for example, for clarity or illustration.

DETAILED DESCRIPTION

The present disclosure will now be described more fully hereinafter with reference to the accompanying drawings, in which example embodiments are shown. This disclosure may, however, be embodied in many different forms and should not be construed as limited to the embodiments set forth herein. Rather, these embodiments are provided so that this disclosure will be thorough and complete, and will fully convey the scope to those skilled in the art.

Embodiments described herein are directed to systems, methods and apparatus for providing real-time alerts and/or notifications regarding the status of agricultural infrastructure resources such as water level, water temperature, trough, water pump, and livestock that are equipped with sensors. The system aggregates and processes the sensed data from multiple fixed and mobile resources and animals using adaptive wireless network and sends adaptively and automatically alert or alerts cost effectively using various messaging methods, such as SMS, MMS, phone call, SS7 signaling, SIP Signaling, VoIP call, HTTP, and HTTPS, over various wireless communications networks, such as cellular, satellite, or UHF, depending on availability, cost and quality of service. Availability encompasses many different embodiments, such as typical operating conditions as well as changes due to malicious interference or exploitation, or other condition(s).

One embodiment is an apparatus that comprises one or more objects; an object is a fixed or mobile physical or virtual article that is equipped with one or more sensors and/or one or more control actuators; one or more objects are grouped to form one or more adaptive basic entity units; one or more adaptive basic entity units are grouped along with an adaptive basic cluster gateway to form one or more adaptive basic clusters; an adaptive basic cluster gateway receives data from one or more adaptive basic entity units through secure wireless channels and is capable of sending alerts and notification as well as receiving control data through a cellular and/or satellite wireless communications connections; one or more basic cluster gateways are adapted to act as adaptive sub-cluster entity units and grouped, along with their served adaptive basic entity units, into one or more adaptive clusters or adaptive higher order clusters.

Each adaptive cluster or adaptive higher order cluster serves one or more adaptive sub-cluster entity using one or more adaptive cluster or adaptive higher order cluster gateways through the use of low rate wireless; each adaptive cluster or adaptive higher order gateway sends alerts and/or notifications as well as receives control data through the use of a cellular and/or satellite wireless communications connections.

As described herein, some embodiments are directed to systems, methods and apparatus for providing real-time

alerts regarding the status of agricultural infrastructure resources, which may be stationary and/or mobile such as water level, water temperature, trough, water pump, drone, and livestock that are equipped with sensors. The system adaptively aggregates and processes the sensed data from multiple resources and animals using low cost readily available wireless local network and sends an alert cost effectively using various messaging methods, such as SMS, MMS, PSTN, VoIP, HTTP, and HTTPS, over various wireless communications networks, such as cellular, satellite, or UHF, depending on availability, cost and quality of service.

Those of ordinary skill in the art realize that the following descriptions of the embodiments of the present disclosure are illustrative and are not intended to be limiting in any way. Other embodiments will readily suggest themselves to such skilled persons having the benefit of this disclosure. Like numbers refer to like elements throughout.

Although the following detailed description contains many specifics for the purposes of illustration, anyone of ordinary skill in the art will appreciate that many variations and alterations to the following details are within the scope of the disclosure. Accordingly, the following embodiments are set forth without any loss of generality to, and without imposing limitations upon, the claims.

In this detailed description, a person skilled in the art should note that directional terms, such as "above," "below," "upper," "lower," and other like terms are used for the convenience of the reader in reference to the drawings. Also, a person skilled in the art should notice this description may contain other terminology to convey position, orientation, and direction without departing from the principles of the present disclosure.

Furthermore, in this detailed description, a person skilled in the art should note that quantitative qualifying terms such as "generally," "substantially," "mostly," "approximately" and other terms are used, in general, to mean that the referred to item, characteristic, or quality constitutes a majority of the subject of the reference. The meaning of any of these terms is dependent upon the context within which it is used, and the meaning may be expressly modified.

The present disclosure addresses the shortcomings, described in the previous sections, of the current practices in managing agricultural and environmental systems, such as mechanical water systems. The disclosure however is not limited in its applicability to these systems.

Embodiments described herein relate to an improved monitoring system in which enhanced adaptability, availability, adoptability, modifiable, reliability, diversity, scalability and cost effectiveness are achieved through the local data aggregation basic or higher order adaptive cluster comprising multiple adaptive basic entity units or adaptive sub-cluster entities and the adaptive basic cluster or adaptive higher order gateway architecture and hierarchy. Particular embodiments of this disclosure are directed to the capabilities to adaptively aggregate sensor data, generate alerts and notifications, communicate control data/messages in the most diverse, versatile, scale-able, reliable and cost-effective method.

The system is adaptable because the system utilizes information gathered previously or accessed from an electronic storage device or location to respond to changing conditions. Previously acquired information and/or signals related to monitoring are used to generate updated or modified, or adapted signals that are processed to generate alerts or status indicators related to one or more objects, which may be physical objects or virtual objects or a combination of physical and virtual objects.

The system is capable of adjusting parameters and information based, at least in part, on iterative information gathered from one or more sensors that acquire information related to one or more objects that are being monitored. These objects may be physical objects or virtual objects. The parameters and information, which are flexible and adaptable may be used to control and/or monitor physical and/or virtual objects.

Physical objects include items such as feed troughs, water toughs, fences, gates, doors, such as barn doors, which may be in an open state or closed state, and associated characteristics, such as being locked or unlocked, temperature, water level, feed level and similar properties and features of the physical object.

Virtual objects may be representations of physical objects, which may be displayed or provided on a user interface, such as a smart phone screen, touch screen or other electronic device. The virtual objects may correspond to one or more physical objects or may be merely an electronic representation in two-dimensions and/or three-dimensions.

Furthermore, a virtual object may also be a software defined object, that is, a process defined in software that may be the subject of monitoring and/or control. An example is a process that is monitoring the memory or CPU consumption or utilization on a device such as a computer, RPi (Raspberry Pi), Arduino, etc. This may be used in support of detecting over-utilization due to a run-away processes or a software malware that could lead to a device or network becoming unavailable.

One or more objects may be grouped, or combined, to form one or more adaptive basic entity units. One or more adaptive basic entity units may be grouped, or combined, with an adaptive basic cluster gateway to form one or more adaptive basic clusters.

An adaptive basic cluster gateway receives data from one or more adaptive basic entity units through secure wireless channels and is capable of sending alerts and notification as well as receiving control data through a cellular and/or satellite wireless communication connections.

One or more basic cluster gateways are configured to act as adaptive sub-cluster entity units and grouped, along with their served adaptive basic entity units, into one or more adaptive clusters or adaptive higher order clusters. One or more adaptive cluster or adaptive higher order cluster serves one or more adaptive sub-cluster entity using one or more adaptive cluster or adaptive higher order cluster gateways through the use of low rate wireless. One or more adaptive cluster or adaptive higher order gateway sends alerts and/or notifications as well as receives control data through the use of a cellular and/or satellite wireless communications connections.

Indeed, the objects monitored may be a combination of physical and virtual objects. Some physical objects may be items, such as a trough, gate, fence, barn door and similar tangible things. The physical object may include a virtual object representation. The virtual object representation may include images, or electronic data that represents additional information for a physical object.

As farmers embrace environmental stewardship and being encouraged and supported by the United States Department of Agriculture, many farmers plan to improve surface water quality by excluding cattle from areas close to streams and rivers as well as establishing riparian buffers along streams and rivers. This exclusion requires establishment of mechanical watering systems for the cattle, which include but not limited to water troughs, fences, gates, and one or more water pump houses.

Currently, while mechanical water systems may be used to refill water troughs, there are some issues.

First, the amount of water can only be measured by manually inspecting each trough and observing the water level. This inspection may need to be done on a regular basis since the water floats used at the troughs to allow the water refilling are prone to mechanical failures. Second, the mechanical systems are susceptible to failure due to the pump house losing pressure. The loss in pressure may be caused by low temperatures, causing the pipes in the pump house to freeze.

Some farmers have installed cellular cameras, which may include a cellular camera for each trough and a means, or techniques, such as video data streaming, still images, photos, or other output from a cellular camera, of acquiring real time visual inspection of the water trough conditions, such as water level and water freeze. However, in addition of being expensive, the visual images/photos have proven to be unreliable.

Today, a farmer relies on physically inspecting the water troughs and water pump houses along with other articles and objects to make sure that the troughs and pump houses are properly functioning and operating.

It would improve farm productivity by reducing costs for labor and/or time spent on location performing visual and/or physical inspection of the mechanical water system.

Therefore, it would be an improvement to have a monitoring, collection, analyzing, alerting and control system. Such a system should be highly available, adaptable, reliable, meet the diverse needs from small to large farms, versatile, scalable, customizable, real time, and cost effective. It would be desirable, for example, to be able to monitor and report the water level and temperature in the troughs and the water pressure of the water pump and the ambient temperature at the pump houses. These characteristics would be assessed and if any of them exceeds a specific threshold, an alert and/or notification would be transmitted to the appropriate personnel via a mobile device, displayed on a monitoring screen, and/or logged into a database for analysis.

In addition to the ability of the system to send alerts and notification messages to users, systems (websites) and/or databases, it is also capable of displaying the same as additional information layer(s) on a map, which identifies the location of the stationary and mobile monitored and/or controlled objects.

The present disclosure is directed to a system that aggregates and processes sensed data from multiple resources, which may be stationary and/or mobile and animals using highly available and adaptable license-free wireless local network and transmits an alert cost effectively (for multiple resources and animals) using various messaging methods (SMS, MMS, PSTN, VoIP, HTTP, HTTPS, audio and video streaming protocols, etc.) over various wireless communication networks, such as cellular, satellite, etc., depending on availability, cost and other quality of service measures.

This provides efficient, high availability, adaptability, reliability, timely and cost effective techniques (methods and tools) to thereby provide real-time alerts and/or notifications to a farmer and/or user on the health of their farms' agricultural infrastructure resources (such as water troughs, water pumps, fences, gates, etc.) and livestock that are equipped with sensors.

As used herein, a sensor is used to sense a physical quantity, condition or state, such as water temperature, air temperature, soil moisture, pH level, water pressure, images, drone elevation and other conditions. The sensors may be mounted or disposed as desired to accomplish the desired sensing.

As used herein, an object including stationary object(s) or mobile object(s), physical objects or virtual object is an article such as a trough, support post, drone, human, animal, tractor, water tank or other tangible item or article or a representation of an actual article or object. This representation may be a virtual object comprising an electronic representation of a physical object, such as a computer generated image of a thing.

As used herein, a basic entity unit comprises one or more objects and has a low rate highly available and optimized radio transmitter unit. This low rate has a predetermined data transmission rate. The low rate data transfer rate may be between approximately 20 kb/s to approximately 250 kb/s.

The highly available transmitter unit is a transmitter that is readily available for data transfer. The highly available transmitter unit is dedicated to transmission between objects in the system. For example, a highly available transmitter unit is a transmitter in an object, such as a water trough, tractor, feed trough, fence post, etc., that transmits data to a gateway device and/or another object. This data is typically sensed data from a sensor disposed on or proximate to the object. This transmitter device typically does not transmit other data such as broadcast radio programming, public radio or other unrelated data. The object may be fixed in location or mobile.

As used herein, an adaptive basic entity and router unit comprises one or more objects and has low rate radio receiver and transmitter units, which may be fixed in location or mobile.

A basic entity and router unit is an object or basic entity that includes adaptive routing and selection functionality.

As used herein in this disclosure a virtual object may be a software defined object, that is, a process defined in software that may need monitoring or control. An example is a process that is monitoring the memory or CPU consumption or utilization on a device such as a computer, RPi (Raspberry Pi), Arduino, etc. This may be used in support of detecting over-utilization due to a run-away processes or a software malware that could lead to a device or network becomes unavailable.

As used herein low rate highly available is a relative term. Low rate RF devices refers to those devices capable of data transfer rate between approximately 20 kb/s to approximately 250 kb/s.

As used herein, highly available communication network and devices, which are typically part of the network, refer to at least portions of a secure communication network with the ability to defend against security attacks such as denial of service (DoS) and interference ensuring high availability.

An adaptive gateway may be an adaptive basic gateway (sub-gateway) or an adaptive cluster gateway (higher order gateway). An adaptive basic gateway includes objects, low rate wireless radio receiver, and wireless cellular and/or satellite alert functionality; it may be stationary (fixed in location) or mobile.

An adaptive basic cluster may comprise an adaptive cluster gateway which serves one or more adaptive basic entity units.

An adaptive sub-cluster entity unit may be an adaptive basic gateway adapted to have low rate highly available wireless radio receiver and transmitter units; it may be stationary (fixed in location) or mobile.

An adaptive sub-cluster entity may comprise an adaptive sub-cluster entity unit and one or more adaptive basic entity units and/or one or more adaptive basic entity and router units.

An adaptive cluster or higher order cluster gateway may comprise objects, low rate highly available wireless radio receiver and wireless cellular and/or satellite alert functionality. Low rate refers to those devices capable of data transfer rate between 20 kb/s to 250 kb/s.

An adaptive cluster or higher order cluster may comprise one or more adaptive sub-cluster entities.

FIG. **1** shows an embodiment **100** that includes components installed at a pump house **102** and at two water troughs **142**(*a*) . . . (*n*) (where "n" is any suitable number). Although two water troughs **142**(*a*) and **142**(*n*) are shown, any suitable number of water troughs (generally **142**) may be used. In this disclosure, monitored and/or controlled objects or basic entity units could be water tanks, water valves, water troughs, water pumps, water pipes, fences, mechanical devices, electronic devices, drones, tractors, mounted cameras, posts, gates, human beings, creatures, animals, livestock, doors, and general machines.

An object, or adaptive basic entity unit, may be equipped with one or more sensors and/or one or more actuators. The sensors may include sensors that are adapted to sense liquid temperature, liquid pressure, liquid level, ambient temperature, location coordinates, power harvested, battery charge and power consumption. The sensors may be used to sense motion as well as when an object moves from a first position to a second position.

The object may be a physical object as described above or a virtual object. A virtual object may be, for example, a digital representation of an object, an electronic representation of an object, a pixel representation of an object or a voxel representation of an object. For example, a virtual object may be an electronic representation of an actual object, such as a field of crops. A drone may obtain a photograph, image data, streaming video or other form of electronic data of a field of crops, which may be obtained from above the field. The obtained image data may not adequately represent the vertical height of the crops, such as the vertical height of corn plants or other vegetation. However, the obtained image data may be manipulated such that a vertical dimension of the crops is provided to a user. A user may then determine whether the height of the crops warrant harvesting, without actually being present at the field because the virtual generated image provides a graphical or digital representation of the field.

The pump house **102** includes GSM module **106**, which may be a cellular phone, operably coupled to a WLAN network **108** and a cellular network **104**. The pump house **102** may also include one or more access points **110**, data processors, applications, aggregator **112**, data processors (with analog or digital capabilities) circuit board **114**, ambient temperature sensor **120**, water pressure sensor **122** and circuitry **116**, such as low rate wireless radio unit, coupled to antenna connection **118**. A sensor comprises an article capable of sensing a physical quantity.

Circuit **116** receives data from a basic entity unit **120**, **122**, which is mounted or positioned to obtain data related to an object (such as water trough). For example, an adaptive basic entity unit may comprise of a water level sensor mounted to an object, such as a water trough. Another example is an adaptive basic entity unit, which includes sensors, mounted on a fence post or a gate.

A source of water, typically a water pump along with a water tank having suitable capacity (not shown) may be used to provide water from the pump house **102** to one or more of the water troughs (generally **142**) based on a typical mechanical float switch or the sensed data from the sensors installed at the particular trough **142**. Sensed data may also include pH level, water and/or stream flow, soil moisture, soil temperature, animal vital signs, images from a camera, images from a drone, drone elevation and other similar parameters.

In the embodiment shown in FIG. **1**, the water trough **142**(*a*) is also shown and the elements are described in general; but apply to any water trough or tank (generally **142**). The elements shown in relation to water trough **142**(*a*) also pertain, and are shown in relation to water trough **142**(*n*).

Antenna **144**(*a*) transmits a signal carrying data from the XBEE low rate radio unit circuit **146**(*a*), which is a circuit on XBEE/Arduino shield **154**(*a*) of circuit **152**(*a*). Battery **150**(*a*), which is operatively coupled to solar panel **148**(*a*), provides power to the water level sensor **156**(*a*) as well as processing element **152**(*a*), shield **154**(*a*) and processor **146**(*a*). While water level sensor **156**(*a*) is shown, any other suitable sensor may be used. These sensors may include pressure sensors, temperature sensors, pH sensors, chlorine sensors, contaminate sensors, etc. The sensors (generally **156**) can provide data that can trigger an alert and/or control messages to actuators installed on objects or adaptive basic entity units, which may initiate or terminate the flow of water from the pump house **102** to one or more of the water troughs **142**(*a*) . . . (*n*).

An actuator, as used herein, is an article, or device, or machine, or switch or other mechanism configured or capable of being used to change the state of a physical object. The data from the sensors, generally **156**, may also be sent to the pump house circuits or modules that are configured to generate and transmit an alert or notification to a location, such as a smart phone, laptop, user interface, or other desired destination.

For example, if the sensor **156** senses that the water is contaminated, or the pH is out of an acceptable range, an alert signal or message can be transmitted to the appropriate location for the most efficient resolution of the issue. This location may be a person, computer, alarm system, smart phone, user interface, database or other remedial activity module.

All units are configured to serve both stationary and mobile objects and are adaptive in terms of their abilities to determine and select the most available and reliable path to deliver the alert service to the intended users and applications.

FIG. **2**, shows an embodiment in which the components are installed on a water trough **142** are shown. The components have been described in relation to FIG. **1**. These include antenna **144**, processor **146**, solar panels **148**, battery **150**, shield **154** and processor **152**. Bi-directional connections between sensor **156** and processor **152** are shown as **209**, **211** and **213**. The sensor **156**, which is shown as a water level sensor, may be mounted in the water trough, along with a float, which is coupled to control a pump in the pump house, which may be utilized to ensure that when the water level sensor **156** in the trough detects a low-water state, an alert is transmitted to the appropriate personnel, smart phone, user interface, display terminal, monitoring systems, display systems, or other suitable location, and/or water is pumped from the pump house into the water trough that has sensed a low water condition.

Thus, a low water condition in a water condition in a water trough has been remediated without human action to physically replenish water into the trough.

FIG. **3** shows components of a pump house **102** according to an embodiment of the disclosure. The components installed at a pump house **102** have been described in relation to FIG. **1** herein. These components include a cellular network, or cellular connection **104**, a user device **106**, which may be a smart phone, user interface, graphical user interface, laptop, personal computer or other device that provides a display or representation to a user. Network **108**, such as the Internet, WAN, LAN, or other connection mechanism is in communication with device **106**. Temperature sensor **120** provides sensed data to circuit board processor **114**.

Water pressure sensor **122** is also in communication with circuit board processor **114**. Circuit board **114** provides signals to a processor **112**, shown as a Raspberry Pi®. Raspberry Pi® processor **112** provides signals to access point **110**. Access point **110** is configured to transmit signals to user device **106** via network **108**. The processor **112** provides output to module **116**, which receives signals from antenna **118**.

FIG. **4** shows an embodiment of an alert transmission according to an embodiment of the disclosure. As shown in FIG. **4**, circuitry **430** receives and processes sensed data sent by sensors on one or more physical and/or virtual objects, which may include one or more water troughs shown as element **142** herein, and those generated at the pump house, shown as element **102** herein. The receptive circuitry **430** determines alerts and provides an alert indicator to an electronic device **428** via a wireless modem **426**, such as a smart phone configured as a GSM modem with message gateway functionality, or other suitable receptive device. The device **426** is adapted to display or output an alert or other indication **420**, **422**, **424**, which is indicative of a sensed condition at a trough (**142**) or pump house (**102**) as shown herein.

The wireless modem **426** is responsible for transmitting to a user and/or a system (e.g., database, website) shown as smart phone **428** the alert and/or notification messages using a wireless data communications network. The wireless modem **426** can be configured to select one of a plurality of networks, which may include, but not limited to, one or more of the following wireless data communications networks: Cellular, Satellite, UHF, and Wireless Local Area network. The modem **426** may be a GSM modem and/or an application running on a phone **428**. The wireless data communications network is selected by the wireless modem according to a set of quality of service measures or criteria including, but not limited to, transmission and propagation delays, availability, time of day, speed, and cost of each of the wireless data communications networks.

The modem **426** provides data to the smart phone **428**, which may be displayed as content **420**, **422** and **424**. Additional content, or messages, may also be displayed on smart phone **428**. As shown in FIG. **4**, multiple messages (**420**, **422**, **424**) related to multiple physical and/or virtual objects may be displayed on a single interface, such as the screen of a smart phone **428**.

To implement an approach that can be customized for different farm sizes, that is, being scalable, the disclosure is based on adaptive nested cluster structure and architecture, as shown in FIG. **5** and FIG. **12**.

FIG. **5** shows a representation of an adaptive cluster (or higher order cluster) **500** comprising a group of adaptive sub-clusters **502** (*a*) . . . (*n*) (where "n" is any suitable number). The adaptive sub-clusters (generally **502**) are served by an adaptive cluster gateway (or adaptive higher order cluster gateway) **506**, which is associated with multiple adaptive sub-clusters, generally **502**.

As shown in FIG. **5**, the adaptive cluster (or adaptive higher order cluster) **500** includes adaptive sub-clusters **502**(*a*) . . . (*n*) and each adaptive sub-cluster (generally **502**), which includes one or more adaptive basic entity units **504**(*a*) . . . (*n*) (where "n" is any suitable number), one or more adaptive basic entity and router units **505** and an adaptive sub-cluster entity unit **508**, which is associated with the adaptive basic entity units, generally **504** and **505** of adaptive sub-cluster **502**(*a*).

Using adaptive sub-cluster **502**(*a*) as an example for descriptive purposes, FIG. **5** and FIG. **12** show that adaptive sub-cluster **502**(*a*) includes one or more adaptive basic entity units **504**(*a*) . . . (*n*) (where "n" is any suitable number) and one or more adaptive basic entity and router units **505**. Adaptive sub-cluster **502**(*a*) also includes an adaptive sub-cluster entity unit **508** that has an associated low rate (LR) highly available wireless radio transmitter **511** and radio receiver **513**. Highly available relates to the network being accessible from multiple locations, or modules, or devices. Highly Available

Each adaptive basic entity unit (generally **504**) includes an associated LR highly available wireless radio transmitter device **512** (generally). That is, adaptive entity unit **504**(*a*) has LR highly available wireless device **512**(*a*); adaptive entity unit **504**(*b*) has LR highly available wireless device **512**(*b*); adaptive entity unit **504**(*c*) has LR highly available wireless device **512**(*c*); and adaptive entity unit **504**(*n*) has LR highly available wireless device **512**(*n*).

Each adaptive basic entity and router unit **505** has LR highly available wireless devices radio receiver **523** and radio transmitter **525**.

Adaptive cluster gateway (or adaptive higher order cluster gateway) **506** interfaces with wireless data communications network **510** and includes LR highly available wireless **515**. Adaptive cluster gateway **506** is in bi-directional communication with adaptive sub-cluster entity units **508**.

In one embodiment, in contrast to the adaptive cluster gateway (adaptive higher order cluster gateway in FIG. **5** or adaptive basic cluster gateway in FIG. **6**) **506**, the adaptive sub-cluster entity units **508** are typically not responsible for sending out alert or notification messages. However, these units **508** send the aggregated digital data streams (sensed data from multiple adaptive basic entity units **504**, adaptive basic entity and router units **505** serving multiple objects and their associated sensors) to an adaptive higher order cluster gateway **506**. Multiple adaptive sub-cluster entity **502** (in FIG. **5** and FIG. **12**) may be used to form an adaptive higher order cluster that is served by an adaptive higher order cluster gateway unit **506**. The adaptive sub-cluster entity unit **508** communicates its digital data streams to the adaptive higher order cluster gateway unit **506** using a low rate highly available license-free radio transmitter **511**.

Under certain rule-based and/or pre-defined criteria (such as failure of an adaptive cluster gateway), a unit (**508** in FIG. **5** and FIG. **12**) initially configured as an adaptive sub-cluster entity unit could automatically become an adaptive basic cluster gateway unit (**506** in FIG. **6**) to its own adaptive basic entity units (**502**(*a*) . . . (*n*) in FIG. **5**) and adaptive basic entity and router units (**504** and **505** in FIG. **5**) and other adaptive sub-cluster entity units (in FIG. **5** and FIG. **6**). Also, a unit that has been initially configured as an adaptive cluster gateway unit (**506** in FIG. **5**, FIG. **6** and FIG. **8**) may become automatically an adaptive basic entity unit (**504** in FIG. **5**

and FIG. **7**), adaptive basic entity and router unit (**505** in FIG. **5** and FIG. **9**) or adaptive sub-cluster entity unit (**508** in FIG. **5**, FIG. **10** and FIG. **12**) in the case of the unavailability of acceptable wireless data communications network services.

In addition to the ability of the system **500** to send alert messages and notification messages to users, smart phones, user interfaces, graphical user interfaces, systems (websites) and/or databases, it is capable of displaying the same alert messages and/or notifications as additional information layer(s) on a map which identifies the location of the monitored stationary and/or mobile adaptive basic entity units **504**, adaptive basic entity and router units **505** and/or objects, such as a water trough, barn door, person, tractor, or virtual object. An indicator may be associated with the sensed data signals. The indicator provides a status level of the importance of the sensed data signals, such as how critical a sensed event is. For example, a low or very low indication of water level will be assigned a higher priority than the temperature reading in a barn.

In the case of a mobile monitored adaptive basic entity unit, the sensed data includes the adaptive basic entity unit and associated objects coordinates for the most current location and status.

A group of adaptive basic entity units **504** (including those configured as adaptive basic entity and router units **505**) along with the serving adaptive basic cluster gateway **506** make up an adaptive basic cluster in the case where the adaptive gateway is also configured and equipped with the capabilities to transmit alerts and notifications to a user or a system, or a smart phone, or user interface or memory location, using wireless data communications networks such as cellular, satellite, UHF, or other wireless services. In the case where the adaptive cluster gateway **506** serving multiple adaptive basic entity units **504**, **505** is configured to transmit its aggregated digital data streams (not alert or notification messages but aggregated sensed digital data streams) to an adaptive higher order cluster gateway using low rate highly available license-free radio transmitter unit, the adaptive gateway along with the served adaptive entity units is referred to as adaptive sub-cluster entity **502**.

FIG. **6** shows the composition of one adaptive basic cluster **600**, which serves multiple adaptive basic entity units **504**(*a*), (*b*), (*c*) . . . (*n*) (where "n" is any suitable number) and adaptive basic entity and router units **505** using an adaptive basic cluster gateway **506**, via transmission and/or reception. The adaptive basic cluster gateway **506** has access to wireless data network **510**, which includes a receiver and transmitter, and LR highly available wireless network **515**. Each adaptive basic entity unit (generally **504**) has an associated LR highly available wireless **512**. Adaptive basic entity and router units **505** have LR highly available wireless radio receiver **523** and LR highly available wireless radio transmitter **525**.

A group of adaptive basic entity units, shown as **504**(*a*) . . . (*n*) and **505** herein, for example, a group of water troughs are served by an adaptive gateway **506** using many to one low rate highly available license-free wireless radio networks **515**. That is, the radio receiver at the adaptive basic cluster gateway location **506** is capable of receiving and processing digital data streams from multiple associated radio transmitters generally **512**, **525** (where each adaptive basic entity unit **504**, **505** is served by a radio transmitter, generally **512**, **525**, as shown in FIG. **6**. The LR highly available wireless radio successful communication typically requires a visible transmission path, also referred to as a line of sight between each of the LR highly available radio transmitters **512** and the adaptive basic cluster gateway LR highly available radio receiver **515**.

In the case where an adaptive basic entity unit, generally **504**, that is served by an LR highly available radio transmitter generally **512**, may not have a visible transmission path, or line of sight, to the adaptive basic cluster gateway **506** (LR highly available radio receiver **515**), that entity **504** may communicate its digital data stream to an entity **505** that is configured to function as an adaptive basic entity and router unit.

Thus, any number of adaptive entity units **504** that do not have direct line of sight, or visible transmission path, with the adaptive gateway radio receiver **515** of basic cluster gateway **506** may utilize basic entry and router unit **505** to receive data from basic entity units **504**(*a*) . . . (*n*) and the basic entry router unit **505** is configured to transmit data received from basic entity units **504**. The data received from one or more basic entity units **504** by basic entity and router unit **505**, may be transmitted to a desired receiver location. This location may be a gateway **506**, user device, laptop, server, drone or any other location suitable to receive data from basic entity and router unit **505**.

More than one adaptive basic entity unit **504** may be configured as adaptive entity and router units **505** for high availability, scalability, redundancy and diversity.

Thus, adaptive basic entity and router unit **505** provides pathway, or conduit, or communication channel or link to permit basic entity units **504** a way to communicate data and information to a destination, such as a smart phone, drone, user interface or other device or memory when the basic cluster gateway **506** is not within a line of sight or is otherwise not able to fulfill its function.

When information is communicated to a drone, the drone can transmit the information to yet another location or destination. Thus, the drone may be a destination or an intermediary transceiver that receives information and transmits the information to another destination.

An adaptive basic cluster or adaptive higher order cluster gateway **506** may also serve objects (stationary or mobile) such as a water trough, tractor, drone, gate, and other physical object or virtual objects that are located at the adaptive basic cluster gateway **506** or the adaptive higher order gateway location. For example, an adaptive basic cluster or adaptive higher order cluster gateway **506** location may be the water pump house that is serving multiple water troughs (examples of multiple entity units, **504**). The water pump itself could represent an object that can be equipped with one or more sensors, such as water pressure sensor, temperature sensor, or other suitable sensor, or information gathering device.

FIG. **7** shows an example of an adaptive basic entity unit, shown herein generally as **504** that may be disposed within an adaptive basic cluster or adaptive higher order cluster which is served by an adaptive basic cluster or an adaptive higher order cluster gateway as shown as element **506** herein. The adaptive basic entity unit **504**(*a*) may be stationary or mobile, or movable.

As shown in FIG. **7**, adaptive basic entity unit **504**(*a*) includes a low rate (LR) wireless transmitter **512**(*a*), harvest energy unit **714**, entity radio transmission unit **716**, entity data multiplexer **718**, a plurality of data processors **720**(*a*) . . . **720**(*n*), where "n" is any suitable number, a plurality of objects **722**(*a*) . . . (*n*), where "n" is any suitable number and a plurality of sensors **724** (*a*) . . . (*n*) and **725**(*a*) . . . (*n*), where "n" is any suitable number. As shown, sensors **724**(*a*) . . . (*n*) are associated with object **722** (*a*) and sensors **725**(*a*) . . . (*n*) are associated with object **722**(*n*).

A number of objects **722**(*a*) . . . (*n*), where "n" is any suitable number, could be grouped into an adaptive basic entity unit (shown herein generally as **504**, **505**). Objects **722** could be physical objects and/or virtual objects or a combination of physical and virtual objects. That is, an adaptive entity unit (shown herein generally as **504**, **505**) may comprise a plurality of objects **722**. Each object **722**, whether physical or virtual and its associated sensors **724** or **725**, in an adaptive basic entity unit (shown herein as **504**, **505**), is typically served by an analog and/or digital data processor unit generally **720**. The data processor units, generally **720**, may provide power, signal conditioning and encoding functions to the sensors **724**, **725** of the objects **720**. The generated data from the data processors, generally **720**, serving multiple objects **722** are aggregated into one digital data stream by an adaptive entity digital multiplexer unit **718**. The multiplexed digital data stream is served by a low rate (LR) highly available license-free wireless radio transmitter **716**. Each adaptive basic entity unit **504** is powered using a harvest energy source **714**, such as solar, thermal, vibration and/or RF.

The adaptive basic entity unit **504** comprises multiple objects **722**, such as troughs, where each object **722** is served by multiple sensors **724**, **725**.

As shown in FIG. **7**, one adaptive basic entity unit **504**(*a*), which is representative of the adaptive basic entity units described herein generally, has a low rate highly available wireless transmitter device **512**(*a*), harvest energy source **714**, entity radio transmission unit **716**, entity data multiplexer **718**, one or more data processors **720**(*a*) and (*n*) (although two data processors, generally **720**, are shown, any suitable number may be used), one or more objects **722**(*a*) and (*n*) (although two objects, generally **722**, are shown, any suitable number may be used). Also shown are sensors **724**(*a*) and **724**(*n*) associated with the object **722**(*a*). While two sensors **724**(*a*) and (*n*) are shown in conjunction with object **722**(*a*), any suitable number of sensors, generally **724** may be used. Object **722**(*n*) has associated sensors **725**(*a*) and **725**(*n*). While two sensors **725**(*a*) and (*n*) are shown in conjunction with object **722**(*n*), any suitable number of sensors **725** may be used.

Harvest energy source **714**, is a circuit that obtains a source of energy, such as solar derived energy or energy from other energy source and uses that energy to power the entity **504**(*a*). Also, the harvest power source **714** may harvest RF, thermal or vibration energy or other sources or forms of energy.

Entity data multiplexer **718** aggregates data from multiple data processors **720** and sends the data to the adaptive entity radio transmission unit **716** which transmits an RF signal through a network, which may be a low rate (LR) highly available wireless network. Entity data multiplexer **718**, which is operatively coupled to one or more processor units, shown as data processors **720**(*a*) . . . (*n*), where "n" is any suitable number (although two data processors, generally **720**, are shown, any suitable number may be used). The data processors are operatively coupled to an associated one or more objects, **722**(*a*) . . . (*n*), where "n" is any suitable number.

As shown in FIG. **7**, data processor **720**(*a*) is operatively coupled to object **722**(*a*) and data processor **720**(*n*) is operatively coupled to object **722**(*n*). The objects (generally **722**) are operatively coupled to one or more sensors **724**(*a*) . . . (*n*) (object **722**(*a*)) and **725**(*a*) . . . (*n*) (object **722**(*n*)).

FIG. **8** shows that an adaptive basic or adaptive higher order cluster gateway **506** may serve an adaptive basic cluster or an adaptive higher order cluster.

As shown in FIG. **8**, adaptive basic cluster, or adaptive higher order cluster gateway **506** includes one or more sensors **724**(*a*) . . . (*n*) where "n" is any suitable number, low rate (LR) wireless receiver **515**, radio receiver unit **834**, a plurality of data processors **720**(*a*) . . . (*n*), where "n" is any suitable number, digital data multiplexer **832**, alert application (app) **830**, message gateway **828**, wireless modem **826**, wireless data network **510** and harvest energy source **714**.

An adaptive gateway **506** has two different RF radio units, one **515** for gathering sensed data from multiple adaptive basic entity units (**504**, **505**) or adaptive sub-cluster entity units (**508**) and the other **510** to send alert and notification messages to individuals mobile and/or stationary devices.

The adaptive higher order cluster and adaptive basic cluster gateways **506** and the adaptive sub-cluster entity units (as shown as element **508** in FIG. **10**) have a common set of functional components. These functional components are shown in FIG. **8** and FIG. **10**. These include the LR highly available license-free radio receiver **515** (element **513** of element **508** in FIG. **10**).

Objects **722** is equipped with sensors **724**, data processor units **720** and a digital data multiplexer **832**. The last two components, as shown in FIG. **8**, are similar to those provided under the adaptive entity unit (element **504** herein) description. The alert and notification application (app) **830** may be configured to communicate to the message gateway component on-board **828**, through wireline connection or through a wireless local area network.

As shown in FIG. **8**, basic cluster gateway, or higher order cluster gateway **506** is in communication with wireless data network **510** and a wireless network through LR highly available wireless receiver **515**. The adaptive basic cluster gateway or adaptive higher order cluster gateway **506** comprises a wireless modem **826**, message gateway **828**, alert application **830**, digital data multiplexer **832**, data processors **720**(*a*) . . . (*n*) where "n" is any suitable number, radio receiver unit **834**, object **722** and sensors **724**(*a*) . . . (*n*).

The alert/notification application **830** is configured to process sensed digital data streams on a periodic basis and determine whether an alert or notification is necessary to be communicated to a user, via a smart phone, tablet, laptop or other user interface or device or display device or a system based on a predefined set of criteria (e.g., threshold crossing of water level, change in temperature, soil moisture range limits, and other user defined criteria). In the case that an alert or notification is necessary, a request is generated by the alert/notification application (app) **830** and is forwarded to the message gateway component **828**.

The message gateway access point, or component **828** is configured to map the alert and/or notification requests into a message or messages to be fed into one or more wireless modems **826**. The message gateway access point or component **828** may be configured to map a request into one of the following exemplary message types: Short Message Service (SMS) text message, Multimedia Message Service (MMS) message, mobile call, Public Switched Telephone Network (PSTN) call, Voice over IP (VoIP) call, web hypertext transfer protocol (http) message, web hypertext transfer protocol secure (https) message, cell phone call, email, text and/or database insertion message. Other message types may also be used.

The alert/notification application component may send a frequent keep-alive data (user configurable/customized times or time periods) on behalf of one or more of the

adaptive entity **502** and/or the adaptive sub-cluster entity units **504** to the adaptive cluster gateway **506**, **508** and/or the users or databases. This is to meet the reliability requirements of the entire system.

In addition, the entire system including the adaptive entity **502**, adaptive sub-cluster entity **504** and adaptive cluster gateway units **506**, **508** may be configured to adaptively re-routing of digital data streams through alternate route(s) in the case of the initially selected route fails or becomes unavailable. The route may be unavailable due to obstacles and/or occlusions in the transmission path between two or more components of the system.

FIG. **9** shows a representation of a basic entity unit that is configured to act as an adaptive basic entity as well as a router on behalf of one or more other adaptive entity units that may not be able to reach the serving gateway component. The lack of ability to reach a serving gateway may be due to a number and/or a combination of factors. These factors include, lack of signal strength, lack of a line of sight, low transmission power or transmitter function, lack of receiver power or function, lack of bandwidth, lack of channel recognition, power failure or any other technical or physical impediment.

The basic entity unit has both a radio transmitter (LR highly available) and a radio receiver unit (LR highly available). As shown in FIG. **9**, the adaptive basic entity and router unit **505** has an entity radio transmitter unit **716** coupled to low rate highly available wireless transmitter **525**, and entity data multiplexer **718**, which is coupled to one or more data processors **720**(*a*) . . . (*n*) where "n" is any suitable number.

Each data processor **720** is coupled to one or more objects **722**(*a*) . . . (*n*), where "n" is any suitable number, having one or more sensors of **724**(*a*) . . . (*n*), "n" being any suitable number and **725**(*a*) . . . (*n*) where "n" is any suitable number. The entity radio receiver unit **936** is coupled to low rate wireless receiver **523**. Harvest energy source **714** is also shown.

FIG. **10** shows a representation of the configuration of an adaptive sub-cluster entity unit **508** as an entity, which may be served by an adaptive higher order cluster gateway (shown as element **506** herein). The adaptive sub-cluster entity unit **508** has receiving and transmitting functionality. LR highly available wireless receiver **513** is coupled to radio receiver unit **834**, which is coupled to data processor **720**(*a*), which is coupled to digital data multiplexer **832**.

Digital data multiplexer **832** is coupled to data processor **720**(*n*) and radio transmitter unit **1033**, which is coupled to LR wireless transmitter **511**. Object **722** and sensors **724**(*a*) . . . (*n*) where "n" is any suitable number, have been described previously herein.

FIG. **11** shows a representation of an adaptive basic cluster or adaptive higher order cluster gateway in communication with an object sensor unit.

The adaptive basic or higher order cluster gateway includes a wireless modem **826**, message gateway component **828** and radio transmit/receive unit **1140**. The adaptive basic or higher order cluster gateway also receives information and/or data via WLAN **1142** and transmits information and/or data via wireless data network **510**.

An alert monitoring unit includes LR (low rate) wireless transceiver **515**, radio receiver unit **734**, data processor **720**(*a*), alert application **830**, digital data multiplexer **832**, alert application (app) **830** and radio transceiver unit **1141** in communication with WLAN **1143**.

As shown in FIG. **11**, alert/notification application (app) component **830** communicates to the message gateway component **828** via a WLAN **1143** and or **1142** rather than directly. This provides flexibility that allows the message gateway component **828** and wireless modem **826** to be located in a separate location from that where elements **830**, **832**, **720**, **734**, **725** and **722** are located. This embodiment includes radio transmit/receive units **1140**, **1141** and wireless LAN (WLAN) **1142**, **1143**.

FIG. **12** illustrates the composition of one adaptive sub-cluster entity **502** which comprises multiple adaptive basic entity units **504**, **505** and an adaptive sub-cluster entity unit **508**. The components shown in FIG. **12** have been described previously herein.

As shown in FIG. **12**, the basic entity and router unit **505** can facilitate communication and transfer of data and information between one or more basic entity units **504** and other basic entity units **504** as well as sub-cluster entity unit **508**.

In view of the above-provided description, this disclosure describes three different use cases:

(1) all adaptive basic or stationary adaptive basic or adaptive higher order cluster gateway (water pump house),

(2) a combination or mix of stationary and mobile adaptive basic or adaptive sub-cluster entity units (cows, drones, tractors, etc.) **504** are served by a stationary adaptive basic **508** or adaptive higher order gateway **506** (water pump house) and

(3) a combination or mix of mobile and stationary adaptive basic or adaptive sub-cluster entity units **504** are served by a mobile adaptive basic **508** or adaptive higher order cluster gateway **506** (e.g., drone)

All units serving stationary and/or mobile objects are adaptive in terms of their abilities to determine and select the most available and reliable path to deliver the alert service to the intended user(s) and/or application(s) and/or destination(s).

Use Case 1 has been described herein in relation to FIGS. **1-5**.

Use Case 2 relates to one or more basic **502** or sub-cluster entity units **504** being mobile and severed by a stationary adaptive basic **508** or adaptive higher order cluster gateway **506**. A mobile adaptive basic **502** or adaptive sub-cluster entity unit **504** may serve one or more objects **722** and their associated sensors **724**, **725**. A mobile adaptive basic **502** or adaptive sub-cluster entity unit **504** may be served by one of the following units: stationary adaptive basic cluster gateway, stationary adaptive higher order cluster gateway or a stationary adaptive basic entity and router unit.

Thus, as described herein, and referring to FIGS. **1-12**, it is to be understood that the embodiments described herein present an adaptive sensing and monitoring system since the role or function of a cluster, router and/or gateway may be interchangeable.

FIG. **1** shows one embodiment in which a sensor **156** is associated with an object, which is a water trough **142**. The sensor **156** collects data regarding the parameters, such as water temperature, water level, water pressure of the trough **142**. The sensed data signals from the trough **142** may be transmitted to the pump house.

Both the trough **142** and the pump house **102** can gather sensed data regarding the status of the trough **142** or pump house **102** and transmit data to a gateway **506**, **508**. Alternatively, the trough **142** and the pump house **102** can collect data from other objects, such as a tractor, fence post, gate, and transmit the sensed data to the trough **142**, the pump house **102** or a gateway **506**, **508**.

The gateway **508** may serve sub-clusters **504**(*a*) . . . (*n*) and router **505**. The gateway **508** is configured to receive sensed data signals from one or more sub-clusters

504(a) . . . (n) as well as router 505. The gateway 508 is also configured to collect sensed data in a manner similar to sub-clusters 504(a) . . . (n) and router 505. Thus, while shown and described as a gateway, the gateway 508 may also gather data from an object or objects.

The gateway 508 has sensors and transmitter 511 and receiver 513. The gateway 508 is configured to collect sensed data, receive data from sub-clusters 504(a) . . . (n) and higher order clusters 502(a) . . . (n) and higher order gateway 506. The gateway 508 may also transmit data to sub-clusters 504(a) . . . (n) and higher order clusters 502(a) . . . (n) and higher order gateway 506.

Gateway 506 has similar functionality as gateway 508. Indeed, gateway 506 may serve sub-clusters 504(a) . . . (n) and router 505. The gateway 506 is configured to receive sensed data signals from one or more sub-clusters 504(a) . . . (n) as well as router 505. The gateway 506 is also configured to collect sensed data in a manner similar to sub-clusters 504(a) . . . (n) and router 505. Thus, while shown and described as a gateway, the gateway 506 may also gather data from an object or objects.

The gateway 506 has sensors and transmitter 510 and receiver 515. The gateway 506 is configured to collect sensed data, receive data from sub-clusters 504(a) . . . (n) and higher order clusters 502(a) . . . (n) and sub-gateway 508. The gateway 506 may also transmit data to sub-clusters 504(a) . . . (n) and higher order clusters 502(a) . . . (n) and sub-gateway 508.

A mobile adaptive basic entity unit 502, 504 may be associated with a stationary adaptive basic 508 or adaptive higher order cluster gateway 506 directly if it has line of sight with that gateway.

In the case that the mobile adaptive basic entity unit does not have line of sight with a stationary adaptive basic or adaptive higher order cluster gateway, then it is configured to utilize a stationary adaptive basic entity that is configured as an adaptive basic entity and router unit as described herein.

Use Case 3 relates to a mobile adaptive cluster gateway configured to serve a group of stationary and mobile adaptive basic entity units. Use Case 3 utilizes a mobile adaptive basic cluster gateway that is capable of sending alerts or sending sensed digital data streams to available stationary adaptive higher order cluster gateway(s).

The mobile adaptive cluster gateway may be deployed as an emergency replacement of failed stationary adaptive basic cluster gateway, or stationary adaptive sub-cluster entity unit, or stationary adaptive higher order cluster gateway.

Each mobile adaptive basic cluster gateway 506, 508 may be assigned a scope of coverage to ensure that all mobile and stationary adaptive basic 502 or adaptive sub-cluster entity units 504 are highly available and reliably monitored and accounted for at all times.

The scope coverage may be enhanced by channel optimization and RF down-converting using energy sampling. Various techniques for down-conversion and energy sampling are described in U.S. Pat. No. 9,288,100, which is hereby incorporated by reference in its entirety herein. The energy sampling and down-conversion techniques enhance the ability for signals to be transmitted between the various objects, adaptive basic entity units, adaptive sub-cluster entity units, and adaptive basic and adaptive higher order cluster gateways.

In the case that the alert/notification application 830 assesses whether an alert request be communicated to the message gateway 506, 508 in response to a threshold crossing event, the process applied by the alert application 830 will minimize the possible false alert due to transient or intermittent events. The procedure involves the alert application 830 to wait until it receives a user defined number of consecutive threshold crossings for a given physical quantity (such as water level) over a user-defined period of time, such as an hour, before it sends an alert request to the message gateway 506, 508.

The number of consecutive threshold crossings to determine an alert request, or alert condition may be based, at least in part, on the number of repeated alerts, type of alert, weather conditions, sensed ambient temperature, time of day or night, whether there is a line of sight communication, whether alert relates to equipment, whether the alert relates to livestock, other sensed conditions and other parameters that affect the severity of a condition.

In the case where an adaptive sub-cluster entity unit 504 is configured to automatically and adaptively become an adaptive basic cluster gateway 506, 508 (capable of sending alert messages using wireless data network), the selection criteria is based, at least in part, on the quality of service measures of the low rate wireless link between the adaptive sub-cluster entity unit 504 and the adaptive higher order cluster gateway 506. For example, if the unit (initially configured as an adaptive sub-cluster entity unit 504) does not receive an acknowledgment from the adaptive higher order cluster gateway 506 after a predetermined number of attempts or user-configured number of attempts (e.g., three attempts) spread over a user-defined time period (e.g., an hour), then the unit 504 reverts to be an adaptive basic cluster gateway 508 and sends the alerts to the intended user or system defined in the alert/notification application.

This dictates that the alert/notification user/system data be continuously synchronized between the alert application 830 on the adaptive basic 508 and adaptive higher order clusters 506.

Each adaptive cluster gateway 506, 508 exercises its own correlation analyses on the sensed data and keep-alive data across objects within an adaptive basic entity unit and across adaptive basic entity units and serving adaptive gateway or adaptive sub-cluster entity units.

The purpose of the correlation is to pinpoint a single downstream failure event that may have triggered or is deemed to be the root cause of multiple upstream alert events and messages. Also, it facilitates the minimization of sending multiple alerts that are caused by the same failure. For example, a failure of the water pump in an adaptive basic cluster may result in many alert events generated by multiple water troughs.

In an embodiment in which a mobile gateway 506, 508 serves a group of stationary and mobile adaptive basic entity units 504, 505, 502, the position of the adaptive gateway 506, 508 is periodically and adaptively adjusted to maximize the number of adaptive entity units 502, 504, 505 served based, at least in part, on a set of quality of service criteria of the wireless links to each adaptive entity unit 502, 504, 505 in the mobile adaptive gateway area of coverage.

In the case a mobile adaptive entity unit 502, 504, 505 moves out of the adaptive gateway 506, 508 scope of coverage, the adaptive gateway 506, 508 sends an alert message to a user or a monitoring system. The alert is sent on a regular basis until the mobile adaptive entity unit 502, 504, 505 is back into the scope of coverage or the adaptive gateway 506, 508 is notified by a user or a system (including other gateways) that the mobile adaptive entity unit has moved into the scope of coverage of another stationary or mobile adaptive cluster gateway 506, 508.

The adaptive basic entity units **502**, **504**, including objects **722** sensors **724**, **725**, object data processors **720**, entity data multiplexers **718** and low rate radio transmitter **716** and receiver units **936** are powered using harvested energy **714**; the harvested energy source **714** is selected from the following sources: solar, thermal, vibration and/or RF based on a predefined set of criteria; where energy is harvested through the use of collectors and power management circuitry configured for one or more of the following energy sources: solar, thermal, vibration and/or RF.

Each adaptive mobile entity unit **502**, mobile adaptive sub-cluster entity unit **504**, mobile adaptive basic cluster gateway **508** or mobile adaptive higher order cluster gateway **506** may be configured to be powered using a harvest energy source **714** (such as solar, thermal, vibration and/or RF).

The alert messages may be programmed to be sent by the adaptive basic gateways **508** or the adaptive higher order cluster gateways **508** between certain time frames, such as certain hours, that are user configurable.

For example, a tractor may be operated by a user having a device, such as a smart phone in their possession. An indication may be received from an object (trough) that the water level is low and the pump house tank does not have an adequate volume of water to fill the trough. The user can receive a notification indicating that the water level in the trough is low and the pump house is not filling the trough. Indeed, multiple users may be contacted and the notification directed to the closest user to address the issue.

Once the issue is resolved all users are notified that the alert condition has been resolved. The determination of the closest user is one parameter, it is also an embodiment that a user who happens to be able to respond to the alert first is notified before the closest user. This may be achieved by a status indicator associated with each user. The status indicator can be modified based, at least in part, by user input indicating an activity level and time of availability of each user.

Some of the illustrative embodiments of the present disclosure may be advantageous in solving the problems herein described and other problems not discussed which are discoverable by a skilled artisan. While the above description contains much specificity, these should not be construed as limitations on the scope of any embodiment, but as exemplifications of the presented embodiments thereof. Many other variations are possible within the teachings of the various embodiments. While the disclosure has been described with reference to exemplary embodiments, it will be understood by those skilled in the art that various changes may be made and equivalents may be substituted for elements thereof without departing from the scope. In addition, many modifications may be made to adapt a particular situation or material to the teachings without departing from the essential scope thereof.

One embodiment is directed to the system apparatus and methods described herein.

Another embodiment is directed to one or more adaptive basic clusters, which are shown as **504**(*a*) . . . (*n*) in combination with **505** or adaptive sub-cluster entities **504**(*a*) . . . (*n*), grouped to form one or more adaptive clusters, also referred to as adaptive higher order clusters, **502**(*a*) . . . (*n*). One or more adaptive basic cluster gateways **508** that are adapted to communicate via a first wireless communication having a defined data rate with one or more adaptive cluster gateways **508** and/or one or more adaptive higher order cluster gateways **506**; where the one or more adaptive cluster gateways **508** communicate with one or more adaptive sub-cluster entities, generally **504**, the adaptive cluster gateways **508** adapted to communicate via cellular, satellite or UHF, and one or more adaptive basic entities **504**(*a*) . . . (*n*) and **505**, operatively coupled to an associated one or more of the adaptive basic clusters **504**(*a*) . . . (*n*), also referred to as adaptive sub-clusters **504**(*a*) . . . (*n*), each adaptive entity **502**(*a*) . . . (*n*) operatively coupled to one or more objects **722**; where the one or more adaptive entities **502**(*a*) . . . (*n*) is configured to receive data from the one or more objects **722**.

Another embodiment is directed to the apparatus as described above where the objects **722** include stationary articles.

Another embodiment is directed to the apparatus as described above where the objects **722**(*a*) . . . (*n*) include non-stationary articles.

Another embodiment is directed to the apparatus as described above where the objects **722** include a trough.

Another embodiment is directed to the apparatus as described above where the adaptive entities **504**(*a*) . . . (*n*) further comprises one or more objects **722**(*a*) . . . (*n*).

Another embodiment is directed to the apparatus as described where the object **722**(*a*) . . . (*n*) further comprises one or more sensors **724**(*a*) . . . (*n*), **725**(*a*) . . . (*n*).

Another embodiment is directed to the apparatus as described above where the sensor **724**, **725** is capable of measuring and detecting physical quantity, condition or state associated with the object **722**.

Another embodiment is directed to the apparatus described above where the adaptive sub-cluster entities **504**(*a*) . . . (*n*) includes sensors **724**, **725** such as a pressure sensor.

Another embodiment is directed to the apparatus described above where the adaptive basic cluster gateway **508** is configured to receive signals from basic entities **504** and/or basic entity and router **505**.

Another embodiment is directed to the apparatus described above where the adaptive basic entities **504**(*a*) . . . (*n*) comprises: an associated digital multiplexer **718** that provides a digital data stream to a transmitter unit **512** via a path having a specified rate low rate highly available radio transmitter unit; where the low rate highly available radio transmitter unit **512** transmits the data stream generated by the digital multiplexer **718** to a low rate highly available radio transmitter unit of the adaptive sub-cluster entity **504** or to another adaptive entity low rate highly available radio receiver unit **515** that is configured as an adaptive entity and router unit **505**; where the adaptive entity and router unit **505** low rate highly available radio transmitter unit **525** is configured to receive its own entity digital data stream as well as the digital data stream from another adaptive entity **504** low rate highly available radio transmitter unit **512** and send a combined signal to the adaptive basic cluster gateway **508**, adaptive sub-cluster entity **504** or adaptive higher order cluster gateway **506** low rate highly available radio receiver unit **515** based on predefined set of criteria.

Another embodiment is directed to the apparatus described above where the adaptive entity **504** comprises: object sensors **724**, **725**, object data processors **720**, an adaptive entity data multiplexer **718**; a low rate highly available radio transmitter **716** and one or more receiver units **512** being powered using harvested energy **714**; where the harvested energy source **714** is selected from the following sources: solar, thermal, vibration and/or RF.

Another embodiment is directed to the apparatus described above where the adaptive cluster gateway **506**

comprises: object sensors **724**, object data processors **720**, digital data multiplexer **832**, low rate highly available radio receiver **515**, alert request application unit **830**, message gateway **828**, and bi-directional data communication wireless modem **826**; where the harvested energy source **714** is selected from the following sources: solar, thermal, vibration and/or RF.

Therefore, it is intended that the disclosure not be limited to the particular embodiment disclosed as the best or only mode contemplated for carrying out this invention, but that the disclosure will include all embodiments falling within the scope of the appended claims. Also, in the drawings and the description, there have been disclosed exemplary embodiments and, although specific terms may have been employed, they are unless otherwise stated used in a generic and descriptive sense only and not for purposes of limitation, the scope of the disclosure therefore not being so limited. Moreover, the use of the terms first, second, etc. do not denote any order or importance, but rather the terms first, second, etc. are used to distinguish one element from another. Furthermore, the use of the terms a, an, etc. do not denote a limitation of quantity, but rather denote the presence of at least one of the referenced item. Thus, the scope of the disclosure should be determined by the appended claims and their legal equivalents, and not by the examples given.

The invention claimed is:

1. A method comprising:

sensing first data at a first object including a sensor and a transmitter;

sensing second data at a second object including a sensor, a receiver and a transmitter;

when a visible transmission path exists between the first object and a gateway device:

transmitting the first data from the first object to the gateway device;

when the visible transmission path does not exist between the first object and the gateway device:

transmitting the first data from the first object to the second object, and

transmitting the first data and the second data from the second object to the gateway device; and

transmitting the first data and the second data from the gateway device to a destination.

2. The method according to claim **1**, where the destination includes a user interface.

3. The method according to claim **1**, where the first object or the second object is a physical object.

4. The method according to claim **3**, where the physical object is a feed trough, water trough, tractor, gate, barn door, fence or fence post.

5. The method according to claim **1**, where the first object or the second object is a virtual object.

6. The method according to claim **1**, further comprising transmitting, by the second object, a sequence of data based, at least in part, on priority.

7. A system comprising:

a first object including a sensor configured to sense first data, and a transmitter configured to transmit the first data;

a second object including a sensor configured to sense second data, a receiver configured to receive the first data, and a transmitter configured to transmit the first data and the second data; and

a gateway including a receiver configured to receive the first data and the second data, and a transmitter configured to transmit the first data and the second data to a destination,

where, when a visible transmission path exists between the first object and the gateway device, the first object is configured to transmit the first data to the gateway device, and

where, when the visible transmission path does not exist between the first object and the gateway device, the first object is configured to transmit the first data to the second object, and the second object is configured to transmit the first data to the gateway.

8. A monitoring system comprising:

a first plurality of objects, each of the first plurality of objects having one or more associated sensors, each sensor configured to generate sensed data signals for the object, each object of the first plurality of objects having an associated transmitter configured to transmit the sensed data signals to a gateway device when a visible transmission path exists between the object and the gateway device, and transmit the sensed data signals to one or more objects of a second plurality of objects when the visible transmission path does not exist between the object and the gateway device,

each object of the second plurality of objects having one or more associated sensors, each sensor configured to generate sensed data signals for the object, each object of the second plurality of objects having an associated transmitter configured to transmit the sensed data signals to the gateway device and an associated receiver configured to receive sensed data signals from one or more of the first plurality of objects, and each object of the second plurality of objects configured to transmit the sensed data signals received from one or more of the first plurality of objects to the gateway device; and

the gateway device operatively coupled to one or more objects of the first plurality of objects and one or more objects of the second plurality of objects, the gateway device configured to receive sensed data signals transmitted from one or more objects of the first plurality of objects when a visible transmission path exists between the gateway device and the one or more objects of the first plurality of objects, and the gateway device configured to receive sensed data signals originating from one or more objects of the first plurality of objects, via one or more objects of the second plurality of objects, when a visible transmission path does not exist between one or more objects of the first plurality of objects and the gateway device,

the gateway device configured to transmit received sensed data signals to a destination.

9. The system of claim **8**, where the destination includes a user interface.

10. The system of claim **8**, where the object includes a feed trough, water trough, tractor, gate, barn door, fence or fence post.

11. The system of claim **8**, where the object is a physical object.

12. The system of claim **8**, where the object is a virtual object.

13. The system of claim **8**, where the second plurality of objects provides a sequence of sensed data signal transmission based, at least in part, on a priority indicator of the sensed data signal.

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